The Use of off-Shore Managed Futures, as a Distinctive Asset Class, Within a Traditional Asset Portfolio: Evidence of Potential Benefits to the UK Investors

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Abstract

This thesis investigates Managed Futures, in particular the use and performance of those derivative securities as an asset class within a portfolio context in relation to UK domiciled investors. Prior empirical evidence tends to suggest that there may be economically significant benefits to UK investors from using off shore US Dollar based Managed Futures. The analyses focus on examining whether allocating some proportion of an investor's portfolio to US Dollar based Managed Futures will materially affect the overall portfolio performance of UK investors.

Three different optimisation or allocation algorithms are used to determine the proportions of the available underlying asset classes (which include Managed Futures) that should be included in the investor's portfolio. These algorithms include two of them that incorporate different aspects of the return distributions of the resulting portfolios that can be expected to be of importance to investors, for example, downside risk minimisation and the minimisation of portfolio's variance by considering the time varying variances of the underlying assets. We also consider time series currency return dependencies and trends that the US Dollar Managed Futures traders claim to be able to profitably exploit via the application of technical trading rules.

We show that using the allocation methods relevant to the distributional pattern of asset returns and the ability of investors to allocate some non-zero proportion of their wealth to Managed Futures tends to result in significant portfolio risk-return benefits to investors. Our analysis also indicates that Managed Futures appear to provide an alternative and, arguably superior, method by which UK investors may achieve diversifications and thereby reduce the return fluctuations of their portfolios, particularly during periods of high market volatility.

By simulating the technical trading rules used by Managed Futures traders, the analysis is able to incorporate trading rules to decide when it is in investors' interests to use either the foreign exchange spot rate or forward contracts. The results do not however show that using US dollar Managed Futures within an equity stock portfolio always helps UK investors. The strongest evidence supporting the effectiveness and consistency of using US Managed Futures within a traditional stock portfolio is only demonstrated during the, highly volatile, 2000 and 2001 time periods.

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TABLE OF CONTENTS

CHAPTER 4

<u>**Appendices**</u>

CHAPTER 5

<u>**Appendices**</u>

LISTS OF TABLES

LISTS OF FIGURES

The Use of off-Shore Managed Futures, As a Distinctive Asset Class, within a Traditional Asset Portfolio: Evidence of Potential Benefits to the UK Investors

Chapter 1

Introduction to the Thesis

1.0 Introduction

The trading of derivative instruments, particularly financial futures and options contracts, has grown rapidly over recent years in response to investor and corporate demands to transfer unwanted financial risks arising from volatility in asset prices, interest rates and exchange rates. In the case of primitive equity and debt instruments, investors have long been able to choose between making their own direct trades in the securities markets or, alternatively, choosing from a wide variety of pooled, managed, indirect investment schemes offered by financial institutions, Prior to the very recent growth in the number and size of (both listed and unlisted) hedge funds, only the Managed Futures industry has provided analogous pooled and managed investment schemes for investors in futures contracts.

This thesis constitutes an exploratory investigation into the Managed Futures industry. The thesis includes descriptions and analyses of Managed Futures products, the trading strategies typically followed by Managed Futures traders and the historical performance of Managed Futures as both a stand alone asset class and as a portfolio hedging instrument. The primary focus of the investigation is, however, an empirical evaluation of the potential risk-return benefits to UK investors from access to Managed Futures products and investment strategies.

Assessing the benefits to UK investors depends upon whether or not the Managed Futures risk-return performance is to be judged as a stand alone asset or in terms of its incremental benefits when added to a traditional well diversified portfolio of stocks and bonds. The analysis is further complicated by the fact that the only developed Managed Futures industry, which is also open to retail investors and which provides reliable performance disclosures, is located in the US. This geographical, institutional and regulatory fact requires the analysis to make a number of additional hedging and strategic assumptions in order to realistically evaluate the performance outcomes in UK£'s for UK domiciled investors.

As will become apparent from the review of the existing, but relatively limited, published research into Managed Futures, a comprehensive analysis of the benefits of Managed Futures is an overly ambitious empirical research objective given the current state of knowledge and the available information and resources. The issues examined in the empirical Chapters of this thesis certainly do not constitute a comprehensive evaluation and, given the exploratory nature of much of the analysis, the results (however strong or otherwise) may not prove to be robust to further testing and refinements in empirical technique adopted by future researchers.

Section 1.1 provides a brief overview of the Managed Futures industry. The reasons underlying its recent growth and development are first discussed, followed by summaries of the risk-return characteristics of Managed Futures, the development of Managed Futures as a distinct asset class and how the benefits to investors should be evaluated within a portfolio context. Section 1.3 provides a summary of the structure and content of the thesis.

1.1 Brief Introduction to the Managed Futures industry

Investments in traditional asset classes, primarily stocks, bonds, and real estate, are the main constituents of investor's portfolios in developed market economies. These traditional asset classes each have distinctive risk and return characteristics and differing degrees of covariance in returns. Individual investors and financial intermediaries such as pension funds and life assurance companies have however typically been constrained by institutional and legal factors from systematically shorting these asset classes. Moreover, particularly with respect to countries other than the US, pension funds and insurance companies are also typically restricted in terms of the amount of their client's funds that can be invested in derivative instruments that might replicate the returns available from shorting. These institutional and regulatory restrictions upon short-selling and investments in alternative asset classes (particularly investments based on derivative instruments) force investors to hold "long only" positions in these traditional asset classes. However, because these asset class returns are often positively correlated, it is clear that these institutional and regulatory constraints deny investors potentially beneficial diversification and risk reduction opportunities.

Over the past 20 to 30 years, developments in electronic information and communication technologies, and the array of new financial markets and types of securities such as futures and options contracts have, nevertheless, significantly increased the opportunities for hedging the risk associated with long positions in these asset classes. The growth of the Managed Futures industry and other alternative investment vehicles, e.g., hedge funds, certainly illustrates the potential demand and hence motivation for alternative asset classes based upon derivative instruments perfectly. In contrast to the traditional use of derivatives primarily as hedging tools, the Managed Futures industry treats investments in derivative instruments as a distinctive and potentially profitable asset class (i.e., Managed Futures funds invest in derivatives with the primary aim of providing investors with superior risk-return outcomes). Managed Futures investments consist of the opportunity for investor to either gain or hedge an exposure to the risks and returns of a portfolio of derivative instruments. The typical Managed Futures portfolio is constructed and managed on the basis that it is possible to adopt superior and profitable trading strategies that exploit anticipated future price movements in traditional asset classes. Due to the low correlation of returns with traditional asset classes, Managed Futures products are also frequently marketed as offering potentially significant diversification benefits to investors within a portfolio context.

The stock market is an economic mechanism for companies to raise capital for risky projects by selling equity to investors. The instruments traded on futures markets provide investors with an economic mechanism by which to price and manage the price volatility associated with an underlying asset, which may be a particular commodity or, as is the case for many financial futures, the level of an equity index portfolio such as the S&P500 or FTSE100. The first futures contracts, many of which have been traded since the middle of the 19^{th} century, were originally based on agricultural commodity prices and these contracts allowed both the farmer and future user of the commodity to hedge their respective price exposures. Futures contracts allow the trading of a risk exposure which, in the case of relatively recent innovations such as financial futures, may derive from interest rate or equity price movements. Due to their low transaction costs and leverage characteristics, futures contracts have also become one of the favoured tools of sophisticated investors who believe that they can profit from their superior knowledge/beliefs about future price movements in the underlying commodity. The substantial growth of funds being committed to specialised futures fund management in recent years illustrates just how effective these practitioners have been in developing a genuinely new asset class.

Since the first Managed Futures program was introduced for individual speculators in 1949, the industry has continued to attract increasingly large numbers of both institutional investors and retail customers. By 1991, there was already an estimated US$20 billion in Managed Futures programs in the United States, Europe, and Asia attracting a large following from institutional money managers and pension plan sponsors.

The greatly increased size of the Managed Futures industry today is, to a large extent, simply a reflection of the uninterrupted growth in futures trading since the late 1960's. Traditionally, the futures exchange markets have brought together commercial hedgers and speculators in an open, competitive marketplace to determine expected future asset prices. As these markets have become increasingly complex, due to the introduction of new futures contracts, more sophisticated strategies, and international market opportunities, users of the futures markets sought more specialised professional advice in managing their futures market assets.

The various types of Managed Futures trading that are available in the US today can be broken down into the following three types. Firstly, investors can purchase the shares of public commodity (or futures) funds. This is similar to buying shares in a stock or bond mutual fund, except that mutual funds are involved in buying and selling securities like stocks and bonds rather than derivative instruments such as commodity futures. Secondly, investors can place funds with a commodity pool operator (CPO), who pools all investors' funds together and employs one or more commodity-trading advisors (CTA) to manage the pooled funds. Thirdly, investors can retain one or more CTA's directly to manage their funds on an individual basis. CTAs normally set high minimum-investment requirements and are only open to investors with substantial net worth and to institutional investors. In the US, the activities of Managed Futures trading are regulated by the Commodity Futures Trading Commission (CFTC).

There are three futures exchanges in the UK (compared to seven futures exchanges in the US). They are the: International Petroleum Exchange, London International Financial futures & Options Exchanges (LIFFE) and the London Metal Exchange. Despite many highly innovative and creative developments, in the UK the growth of activity levels in respect of trading derivatives has not been anything like as phenomenal as in the US. As a result, Managed Futures products and other derivatives based trading platforms are not as well developed in the UK as they are in the US, at least in relation to the on-shore UK market. Informal enquiries with an investment firm based in London revealed that in 1998 they were aware of several CTA's operating in

London, all of whom used associated offshore locations such as Jersey, the Channel Islands, and Bermuda etc. to conduct their Managed Futures related trading activities.

There has been some recent interest from the UK regulator, i.e., the Financial Services Authority (FSA), in investigating the feasibility of developing a UK on-shore market in relation to such trading activities. In August 2002, the FSA published a discussion paper about the marketing and selling of hedge funds in the UK to retail investors, which demonstrates the growing interest in developing an on-shore Hedge fund market. The Managed Futures industry is regulated by the CFTC in the US. However, Managed Futures funds are also a form of hedge fund. Even though hedge funds in the US are not as tightly regulated as Managed Futures funds, some types of trading strategies/activities of hedge funds resemble those of Managed Futures funds, e.g., the use of financial and commodity futures and other widely traded and liquid derivative instruments. Obviously, many hedge funds adopt trading activities that use more exotic combinations of derivative instruments and generally claim to be following complex and profitable strategies. The development of an on-shore hedge fund market would, therefore be expected to have an immense positive impact on Managed Futures funds, and the popularity of other trend following type investing in the UK.

Though the development of an on-shore Managed Futures industry in the UK similar to that successfully operating in the US is unlikely in the near future, the use of Managed Futures by many UK-based institutional and corporate investors is quite significant and there are several well established operations in off shore markets. This enables investors, especially high net-worth individuals, corporations and institutions, to access these instruments. The empirical studies carried out in this thesis are therefore relevant to UK investors as they have been designed with the explicit aim of exploring the potential benefits of using off shore Managed Futures within UK investment portfolios.

1.2 Structure of the Thesis

The main focus of this thesis is an examination of the asset allocation decision and the subsequent portfolio performance differences achieved by UK investors from being able to include in their portfolios Managed Futures investments. Hence, the performance of Managed Futures will be evaluated in terms of its incremental benefits when investors have an opportunity to include Managed Futures within a traditional stock portfolio.

It is noted that the development of Managed Futures is still rather limited outside of the US, particularly in relation to UK and other European based markets. Still, empirical evidence in the academic literatures can be found which appears to support of the use of Managed Futures by UK domiciled investors. The empirical analysis which focuses on whether allocating some proportion of an investor's portfolio to Managed Futures will affect their overall portfolio performance is especially pertinent given the increasing interest by the FSA to explore the feasibility of developing an on-shore market for hedge fund products in the UK. The research findings in this thesis could, therefore, eventually have important implications for public policy initiatives in this area.

Chapter 2 consists of a review of the relevant academic literature on Managed Futures trading and performance. Chapter 3 is devoted to describing the data sources and research methods used in the later empirical Chapters. This is followed by three empirical Chapters, each of which examines a different aspect of the allocation decision and the effect that Managed Futures has upon portfolio performance. Each of these three empirical Chapters uses a different optimisation or allocation algorithm that attempts to incorporate different investor preferences in relation to the returns and incremental risks associated with Managed Futures. These investor preferences are, firstly, the preference for a lower downside risk (Chapter 4). Secondly, investor's preference for a lower interdependence between assets' returns (Chapter 5). And, finally, investor's preference that relate to viewing currency as an asset class in creating value to the asset portfolio (Chapter 6). Currency issues are particularly important in this context because the Managed Futures data that we use are necessarily the off shore US dollar based activities.

Before going into the details regarding the asset allocation process, Chapter 2 first provides a basic general understanding and review of Managed Futures. This includes a review of the Managed Futures Industry and the Performance Analysis of the use of Managed Futures as both a stand-alone investment and as an addition to a n existing well-diversified stock/bond benchmark portfolio.

The literature review in Chapter 2 begins with Lintner's (1983) seminal study. Apart from being the first serious study to evaluate the performance of Managed Futures as a stand alone investment, Lintner (1983) also analysed the potential impact of adding Managed Futures to a portfolio of stocks (or stocks and bonds). First, Lintner established that both the "commodity trading advisors" (CTAs) and public commodity funds in his study had low correlations with both stocks and bonds. For the minimum risk portfolio of CTAs, the correlation coefficient versus stocks was –0.07 and versus bonds was 0.15. For the minimum risk portfolio of public commodity funds, it was 0.23 versus stocks and 0.15 versus bonds.

Using a performance evaluation framework based upon the return-to-risk ratio, Lintner then examined whether adding a sub-portfolio of Managed Futures to portfolio of stocks (or stocks and bonds) significantly improved the risk/return trade-off of those portfolios. Lintner found that any beneficial consequences of adding Managed Futures to a traditional portfolio of stocks and/or stocks and bonds depended primarily upon the diversification benefits, which were highly dependent on the correlation between Managed Futures and the traditional asset classes. Considering a hypothetical case when the correlation is zero, the sub-portfolio of Managed Futures only needed to have a positive return-to-risk ratio for benefits to emerge from adding Managed Futures to the stock or the stock/bond portfolio. As Lintner (1983) found, the correlations between Managed Futures and both stocks and bonds tended to be low. It is expected, therefore that diversification benefits may be present when the sub-portfolio of Managed Futures is included within the stock or stock/bond portfolio. Other literatures using different time periods and data will also be reviewed in this Chapter. Most of these other studies reach similar conclusions to those of Lintner (1983) regarding the effectiveness of Managed Futures as an additional source of diversification to a stock and bond portfolio.

In Chapter 4, we first provide a brief review on the use of appropriate allocation models when skewness is present in the return series of a portfolio. This is because, as illustrated by the analyses of, amongst others, Fung and Hsieh (2001), the distributional characteristics of returns of trend-follower strategies typically exhibit positive skewness. Hence, since Managed Futures funds overwhelmingly tend to adopt trend following trading strategies, positive skewness is also likely to be present in Managed Futures returns. Therefore, the use of appropriate allocation models when such positive skewness is present is an issue that is worth investigating. Nawrocki (1999) explains that there have been numerous techniques developed over the years in order to implement the theory of portfolio selection. Amongst these techniques is the downside risk framework or, as it is more commonly known, the Lower Partial Moment model.

Nawrocki (1999) evaluates the use of Lower Partial moments with respect to the application of below target variance and skewness. Skewness is defined as the measure of the asymmetry of the return distribution. If there is no skewness, then the distribution of the returns is symmetric. If there is significant skewness, then the distribution is statistically asymmetric. When the skewness of an asset return distribution is negative, then the downside returns will have a higher frequency of occurrence than the upside returns, i.e., losses when they occur will tend to be large losses. When the skewness of the distribution is positive, then the upside return will have a larger magnitude of returns than the downside returns. And when losses occur, they will be smaller and when gains occur, they will be greater. The traditional minimum variance model considers variance as the risk measure, and therefore when significant skewness is present in the return distribution of an asset, using minimum variance model within a portfolio asset allocation framework may produce sub-optimal outcomes.

The introduction of the lower partial moment criterion to allocate portfolio funds places different weights on assets that reveal significant skewness of returns. One advantage of using the Lower Partial Moment is that this framework focuses on analysing risk in terms of below target variance. Therefore only below target variance is assumed to be relevant or indeed captured in the return distribution. Incorporating such types of risk analysis into the Lower Partial Moment algorithm framework, allows below target variance to be adjusted for differing degrees of skewness in the asset allocation process and subsequently produce portfolio return-downside risk outcomes that may reflect investor risk preferences more accurately.

Using this method, the asset allocation in this Chapter takes into account five Managed Futures instruments (i.e., trend-following CTA, discretionary CTA, diversified CTA, currency CTA, financial CTA) and the seven MSCI Stock indexes (i.e., MSCI Stock indexes for USA, Japan, West Germany, France, Switzerland, Canada and the UK) that are used within a portfolio. Four years (1990 to 1993) time periods in the allocation algorithm are used and this analysis provides evidence that allowing for the adjustment for skewness within a portfolio helps to produce relatively better out sample holding period returns, ranging from about 79% to 89%. The highest returns occur where the portfolio is adjusted for the least skewness, while the lowest returns occur when the portfolio incorporates the highest level of skewness. This shows that skewness does affect portfolio returns. When compared to using the minimum variance approach for asset allocation in the same time periods with the same underlying assets, the minimum variance approach only managed to produce an out sample holding period return of about 77%. This then shows that the choice of asset allocation model is important and will affect portfolio returns when the underlying assets' exhibit positive skewness.

In Chapter 5, the Empirical Study assumes the UK investor has a preference for minimum portfolio risk arising from time varying variances. Oberuc (1992) analysed the effect of using Managed Futures in combination with a number of non-US investment portfolios. The main rationale of Oberuc (1992) stems from the fact that as markets have become both more integrated and international, diversifying a portfolio across equities has become less successful than in the past, especially when most underlying stock indices are affected by the same non-diversifiable market risk factors – a situation which was very evident in the case of the October 1987 crash.

The main objective of Oberuc (1992) was to discover whether there were similar benefits accruing to European investors from including Managed Futures in a stock and bond portfolio. Since the 1987 October stock market crash, the world's stock markets have experienced a number of other shocks and crises that have significantly increased market volatility. Crises include the Asian currency crisis (1997), the Russian Bond default, the Long Term Capital Management crisis (1998), the collapse of the technology stock price bubble (2000), September 11th (2001) and the various (e.g., Enron, WorldCom, etc.) accounting and corporate governance crises. This Chapter aims to test whether UK investors would be better off if they were allowed to use Managed Futures as part of the UK portfolio that consists of the MSCI EAFE index, compared to the case when the MSCI EAFE market index is combined with the MSCI North America market index. The market interdependence model, consisting of a bivariate GARCH (1,1), shows that the conditional covariance between the Managed Futures and the EAFE index appears to be much lower. However, the conditional covariance between the North America and the EAFE index appears to be much higher. Comparing the two portfolios shows that the Managed Futures/EAFE portfolio returns has lower volatility and much higher minimum returns of about –3.5%, while the US/EAFE portfolio has more negative returns of about –11%. This shows that the lower conditional covariance arising from using Managed Futures has had an impact on reducing portfolio volatility.

In Chapter 6, an assessment of the potential benefits of using Managed Futures within a UK portfolio that consists of the MSCI stock index portfolio is investigated. This analysis does not take into account the characteristics of distributional returns, unlike the analyses undertaken in Chapters 4 and 5. Instead, the fact that Managed Futures are traded off shore and in US dollars is central to the asset allocation method investigated in this Chapter. The analysis focuses on viewing currency as an asset class and evaluates portfolio outcomes from the point of view of a UK domiciled investor, i.e., where returns need to be expressed in UK pounds and which therefore necessitates a conversion of the portfolio returns from US Dollars to UK pounds. This then reveals how conditionally choosing either the spot rate or the forward contracts in the conversion process might affect the returns of portfolio (that used Managed Futures) expressed in UK pounds.

Finally, Chapter 7 contains a summary of the main issues the thesis has addressed. This includes a discussion and review of the main empirical results and their implications for investors. The limitations of the analysis and some suggestions for future research will also be presented in this concluding Chapter.

Chapter 2

The Managed Futures Industry and a Review of the Performance of Managed Futures

2.0 Introduction to the Chapter

This chapter has two main objectives. The first objective is to provide an overview of the current instruments, market, and historical development of the Managed Futures industry. This overview is undertaken in section 2.1. This section first examines the main characteristics, trading mechanisms and strategies associated with Managed Futures instruments and then reviews the literature concerned with the factors that help explain the current size and structure of the industry, particularly the well-established US retail market in Managed Futures. The second objective of this chapter is to provide a review of the evidence concerning the main uses of Managed Futures by investors, i.e., as stand-alone investment and/or as a portfolio asset, and the empirical evidence concerning the past performance of Managed Futures funds. This review of the literature concerning the uses and historical performance of Managed Futures is undertaken in section 2.2. Given the different objectives of investors in Managed Futures and the existence of potential alternative investments, e.g., hedge funds, the analysis includes considering the historical risk/return performance of Managed Futures funds as a portfolio investment and in relation to comparable hedge funds performance outcomes. This is to be discussed in Section 2.3. The final section of the chapter, 2.4, provides a brief summary of the main points to emerge from the material reviewed and considers their implications for the future development (particularly outside of the US) of the industry and the primary issue, research design and empirical testing undertaken in later chapters of this thesis.

2.1 The Managed Futures Industry

2.1.1 Managed Futures

Futures contracts have, like stocks and bonds, been traded on organised Exchanges for many decades. Historically, futures contracts have been used primarily as a hedging instrument, or as a form of insurance, by both producers and consumers of commodities to avoid price risks. Liquidity and the efficient transfer of price risk in commodity markets has generally been greatly increased by the presence of sophisticated investors willing to trade futures contracts to take on risks other investors were not willing to bear and/or to exploit their assumed superior knowledge in respect of future price movements in the underlying commodity. Though futures contracts are, in themselves, fairly simple instruments with easily understood trading and pricing mechanisms, Managed Futures funds offer investors the opportunity to share in the risks and returns of an asset that essentially consists of a portfolio of futures trading strategies. As the latter are necessarily both complex and non-transparent, Managed Futures products have until recently been excluded from the mainstream investment mix associated with both institutional pension fund portfolios and the personal portfolios of most retail investors. The rapid development of many new and existing commodity and financial futures and options markets over the past 20 years has, however, resulted in trading volumes of these "derivative" instruments far outstripping the value of transactions in the underlying commodities or financial assets.

The more recent development of an apparently well structured "Managed Futures" fund management industry available to retail investors in the US suggests that investors are increasingly beginning to view these funds as providing a genuine alternative investment opportunity, as opposed to simply fulfilling a traditional hedging function. The substantial growth in the level of investment funds being committed to specialist Managed Futures funds certainly indicates that investors are increasingly prepared to allocate some proportion of their own and/or clients' wealth to Managed Futures products.

The shift by institutional investors such as managed funds, endowments and trusts, and bank trust departments towards viewing Managed Futures as one segment of a well-diversified portfolio is well documented. The "Centre for International Securities and Derivatives Markets" (CISDM), affiliated with the Isenberg School of Management, University of Massachusetts, produces the most authoritative research regarding the volume of assets under management by the Managed Futures industry in the US. Their latest survey, reported in Cerrahogiu & Pancholi (2004) shows that "assets under management" has grown from slightly more than \$20 billion in 1996 to more than \$80 billion as at the end of 2003.

Another survey by Eurohedge (see www.eurohedge.com), which is the trade publication for the European Hedge fund community, shows an annual mid-year (i.e. as at 30th June 2004) total of \$216 billion of assets under management by the European hedge fund community, an increase of over 70% from \$125 billion at the end of June 2003 and more than 25% above the \$168 billion estimated to have been invested at the start of the year, January 2004.

Managed Futures funds are, of course, simply a subset of the hedge fund industry and the survey provides a breakdown of the $216 billion assets under managements, by the type of trading strategies adopted by the hedge funds. The volume of assets under management that were classified as 'Managed Futures' strategies was $20.3 billion as at July 2004, a significant increase from the $12.7 billion invested as at July 2003 and the $16.2 billion invested as at the beginning of January 2004.

The Eurohedge research also shows that, out of the $216 billion assets under management by the hedge fund community, more than 50% of the managers are based in London. London, therefore, remains, by far the dominant centre for European hedge fund activity, accounting for more than 75% of the European total assets under management. The growth of the Managed Futures industry in Europe over the recent past appears to reflect attempts to emulate the success of the established, Managed Futures industry operating in the United States. The Managed Futures Industry in Europe and the UK is, however, still very small and, because retail investors are excluded, largely unregulated. These factors, unfortunately also imply that there is very limited information, data or documentation available relating to European developments. Consequently, the development, trading strategies and regulatory structure of the Managed Futures industry in the US will be the main source of information where the data are gathered and based upon, to be used in this thesis to describe, illustrate and discuss the concepts and investment strategies available from Managed Futures.

2.1.2 The Development of the US Managed Futures Industry

The first Managed Futures program was introduced for individual speculators in 1949 and over the subsequent 50 years the industry in the US has grown steadily and now attracts a large number of followers from amongst both institutional investors and retail customers. By 1991, there was already an estimated US$20 billion in Managed Futures programs in the United States, Europe, and Asia attracting a large following from institutional money managers and pension plan sponsors.

Traditionally, the futures markets have brought together commercial hedgers and speculators in an open, competitive marketplace to determine an asset's price at a single point in time. As these markets became increasingly complex, due to the introduction of new futures contracts, more sophisticated strategies, and international market opportunities, users of the futures markets sought more specialised professional advice in managing their futures market assets.

One major incentive for Managed Futures investments appears to stem from their ability to offer risk reduction through diversification while still offering returns comparable to other traditional investments (e.g., domestic and international equity indexes). The empirical evidence relating to historical returns, also indicates that Managed Futures have historically had low correlations with a wide range of national and international stock and bond indexes as well as many commodity indices.

Research on traditional security markets has also shown that market prices react to unexpected changes in micro (e.g., earnings) or macro (e.g., interest rates, GNP) information. Trading futures contracts based on forecasts of these fundamental variables may likewise result in positive return/risk tradeoffs. The importance of this research is that Managed Futures may allow investors to profit from market trends or unexpected changes in information in ways that are not easily available from other managed assets such as stock-based mutual funds. This is because the cash market's transaction costs and institutional restrictions on short selling and leverage make it unprofitable for mutual fund managers to engage in strategies that involve short positions. Hence, Managed Futures can, in principle, enable an investor to capture those returns available in the spot market more cheaply (e.g., replicate cash indexes with lower transaction costs) and capture opportunities not easily found in spot markets (i.e., the ability to sell short and to alter the degree of leverage in asset positions).

In short, the chief benefits of using a professionally-Managed Futures program is that it appears to offer investors some features not commonly found in other investments. The primary additional benefits typically claimed by Managed Futures fund managers are:

1) Portfolio diversification that can provide non correlated returns to other assets such as stock, fixed income instruments, cash and real estates.

2) Multiple professional trading advisors whose performance, taken in aggregate, can provide greater opportunities for higher returns at lower risk.

3) Potential access to new investment strategies utilising the cash, forward, options, and swap markets to supplement the initial futures positions.

4) Liquidity and mark-to-market reporting.

5) Products designed with a guaranteed return of a client's original investment.

6) Limited liability if the futures program is part of a limited partnership.

7) Economies of scale as positions are pooled.

2.1.3 The Types of Managed Futures and their Features

A professionally-Managed Futures program[1] can be undertaken via any of the following 3 methods:

1) Managed Futures accounts (Commodity Trading Advisor),
2) Private Futures Fund (commodity pools), and
3) Public Futures (commodity) Funds.

2.1.3.1 Managed Futures Accounts

A Managed Futures account is like any other brokerage account established to trade in futures except that the responsibility for determining what rates to make and at what time, including discretionary authority to direct trading for the account, is delegated to a professional trading advisor. An important feature of Managed Futures accounts is their low cost and large minimum capital requirement structure.

2.1.3.2 Private Futures Funds – Commodity Pools

A private futures fund or commodity pool is a form of investment trust. It is a syndicate or similar form of enterprise that is engaged in the business of investing its clients' pooled funds in a diversified portfolio of futures contracts. Private futures funds are limited to fewer than 35 investors. They may however have an unlimited number of accredited investors that is people having a minimum net worth of US$1 million or an annual income in excess of US$200,000.

2.1.3.3 Public Futures (Commodity) Funds

A public futures fund is a professional managed limited partnership, offered to investors by prospectus. While individual funds may differ in terms of detail, the typical fund will have the following characteristics:

1) Most funds trade in many futures, options, and forward contracts on financial instruments, foreign currencies and commodities. They frequently hold financial instruments directly (e.g., using Treasury bills for margin against their futures.

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[1] Most features of Managed Futures programs listed in Section 2.1.3 can be found in Topbas (1993).

transactions). Most fund prospectuses stress diversification and the ability to take long and short positions in commodities (i.e., to buy and sell futures contracts).

2) Most funds can only be purchased for a short time after the initial prospectus, but allow investors to liquidate their positions at net asset value at monthly (sometimes quarterly) intervals. A monthly rate of return can also be computed.

3) Most funds use technical and trend-following systems to decide whether to take long or short positions with respect to any commodity (futures contracts).

4) Most funds also incur high management fees and transaction costs relative to other types of asset management such as mutual funds.

2.1.3.4 Persons Involved In Running the Managed Futures Funds

There are different parties involved in running a typical futures fund. These are:

1) The sponsor/general partner, who may be responsible for putting together the prospectus and/or other promotional material, structuring and establishing the fund. The sponsor/general partner of a fund could be a trading manager, a brokerage house or a trading advisor.

2) Trading manager(s) who is/are responsible for specifying longer term investment strategies, selecting the advisors to meet specific return/risk parameters, monitoring performance, and reallocating assets to trading advisors if required.

3) Trading Advisor(s), who is/are specialist futures trader(s) taking day-to-day responsibility for running the fund and making investment decisions.

4) Brokers and sometimes sub-brokers for the execution and clearing of trades.

5) A custodian, who is appointed by the manager to be responsible for the safekeeping of the fund's assets.

6) Possibly, in the case of funds with a large number of participants, a registrar, who is responsible for maintaining the register and issuing and redeeming units, and issuing certificates?

7) Lawyers, appointed by the sponsor in its own jurisdiction to help with the establishment/promotion of the fund, advising on taxation, marketing restrictions and often local law governing the constitution and local taxation of funds.

2.1.3.5 Operating Costs of a Futures Fund

The professionals running these funds obviously ensure that they are "adequately" remunerated for their efforts. They tend to be remunerated primarily by way of management and incentive fees and brokerage fees.

The remuneration packages of fund managers characteristically include:

i) an annual management fee based on a percentage of the fund's Net Asset Value.

ii) a placing fee on the issue of units to investors calculated as a percentage of the sum subscribed. Usually deducted by the manager from subscription moneys received. Sometimes this "front-end load" is waived or reduced by the managers at their discretion on a case-by-case basis in order to attract large subscriptions.

The remuneration of the advisors generally includes:

i) a basic fee calculated as a percentage of fund net asset value sometimes payable by the managers out of the management fee.

ii) a performance based fee (incentive fee) payable out of the property of the fund on "new profits" (i.e., above a predetermined "hurdle rate", profits in excess of original subscription moneys, or (most commonly) on a "peak-to-peak" basis, i.e., a comparable accounting period).

An associated broker may profit from transacting business for the fund. Provided proper disclosure is made, the fee levels are perceived to be "reasonable" and there is no "churning", this is legitimate and indeed customary.

At this point, it is worth noting that the operating costs of public futures funds are very important in terms of their prospective performance and consequently, their general acceptance as a valuable alternative investment medium.

2.1.4 US Managed Futures Industry – Stages of Growth and Industry Development

Looking back, it is possible to view the industry as having developed in three distinct phases. The first phase covers the period from 1972 to 1977, when the initial sign of what was to become the Managed Futures industry emerged. The second stage occurred from 1978 to 1987, which was a period that produced many of the major innovations that shaped the industry as it exists today. The third period, which began around 1988 and which continues through to the present, has been an era of expansion in which new groups of investors, from all over the world, have begun to participate in the industry.

However, no history of the Managed Futures industry would be complete without a discussion of the role played by Richard Donchian, considered by many to be the father of the Managed Futures industry. After graduating from Yale in 1928 he began his Wall Street career. He developed many of the early trading systems, wrote extensively on his research, and trained several early advisors. In 1981, sixteen of the nineteen advisors who managed public funds were either trained by Mr. Donchian or employed the techniques he developed to manage client money. He retired in 1991 after more than sixty years of involvement in the industry he played a significant role in creating.

2.1.4.1 1972 to 1977 - The Beginning of the Industry

The period of time between 1972 and 1977[2] is considered to be the beginning of the industry for three reasons. Firstly, the oldest successful advisors all trace their beginnings to this time. Secondly, extraordinary market conditions, characterised by large price volatility and great uncertainty regarding the future supply and price of many commodities, particularly oil, had begun to attract investors to Managed Futures. Finally, the first financial futures contracts - foreign currency futures – began being traded during this period.

The industry would not have developed without these two key components: advisors with the capabilities of trading in a wide variety of markets including the financial markets and investors who actively sought their services. Between 1972 and 1977 these factors came together for the first time.

The early advisors who began trading in this period typically used intermediate or long-term trend-following systematic approaches. Major elements in their approaches generally included diversification over several markets, mathematical criteria for trend identification, adequate capitalisation, and strict money management rules. The trading style developed during these years is still used by many successful practitioners today.

[2] The development of the Managed Futures industry between 1972 and 1977 are mostly gathered from the website of managed funds association, www.mfainfo.com. Most material in Section 2.1.4 is gathered from the same source.

The interval between 1972 and 1977 was also one of the most exciting times ever in financial history. This short span of time witnessed the highest inflation rate since 1919, the largest economic decline since the Depression, the steepest decline in stocks since the 1930s, and the highest rates for bonds since the US Civil War. To add to the uncertainty of the times, the President of the United States was found to be involved in the "Watergate scandal" and had to resign, there was an oil embargo caused by a war in the Middle East, and two major droughts that affected farm prices worldwide. Clearly these were unusual times.

These events, and the desire for many investors to hedge the implied price risks, sharply increased investors' awareness of and interest in Managed Futures. In addition to hedging, other investors began to notice that many Managed Futures advisors were able to produce positive returns from the money invested in futures contracts on behalf of their clients. Thus, the idea and practice of viewing Managed Futures as a distinctive asset class began to take hold as investors sought out those advisors who appeared to demonstrate an ability to profit from these events. The performance of some of the early advisors during this period certainly gave them credibility and staying power. Among the firms that trace their beginnings to this period are Campbell & Co., Dunn Capital Management, and Millburn Ridgefield.

During this period, the first financial futures exchange - the IMM - was founded, which permitted advisors and investors to begin trading currency markets in addition to traditional tangible commodities such as silver, wheat, and sugar. After currency futures, a broad array of financial products began to appear, such as futures contracts on stock indices, foreign government bonds, and U.S. interest rates.

The growth of the industry during these years spurred the United States Congress to create the Commodity Futures Trading Commission in 1974, thereby establishing a comprehensive legal and regulatory framework for the Managed Futures industry. Although there were certainly many prior innovations that facilitated the development of the industry, it was this unique period, when the investors, the markets, and the economic events all came together, that created the necessary and sufficient conditions for the industry to become firmly established.

2.1.4.2 1978 to 1987 - Building the Foundations of the Industry

It is doubtful that the Managed Futures industry will experience another period of change and innovation as great as that seen during the subsequent ten years. Some of the more important, but by no means all, of the developments that occurred during this period include: the expansion of overseas exchanges and markets, the creation of new Managed Futures vehicles, the introduction of alternative trading styles, the entrance of powerful new sponsoring firms, the initiation of the first academic research on Managed Futures, and the development of the industry's first newsletters and conferences.

This period saw a rapid expansion in the number of futures exchanges and markets worldwide. Important new exchanges were established in London, Paris, Germany, Tokyo, Singapore, and Sydney. By the early 1990's there were approximately 25 new financial futures capable of being traded that had not existed ten years before.

In addition to new markets, new investment vehicles were developed. Public futures funds were first offered in 1978, and by 1981 there were 30 active funds. The first zero coupon bonds were created in 1981, and within a few years, they were being used to support fully guaranteed futures funds.

The development of these guaranteed products had a powerful marketing allure since they directly addressed investors' biggest concern with futures funds, the perceived level of risk. The ability to offer a guaranteed return of principal has been one of the most important factors in attracting investors to Managed Futures since the early 1980's.

Not only were investors attracted to new markets and new investment vehicles, but to new trading approaches as well. Beginning in the early 1980's, various discretionary advisors - advisors who do not use a mathematical system but who trade as their information, trading experience, and instincts dictate - began to generate investor interest. Soon fundamental advisors were also offering their services. This multiplicity of trading approaches allowed the industry to appeal to a much wider spectrum of investors.

These developments in the Managed Futures industry also caught the attention of Wall Street. During this period, some of Wall Street's largest investment firms such as Dean Witter, Merrill Lynch, Smith Barney, Prudential, and E. F. Hutton began to support the industry with various public and private offerings. Many of these same firms remain as some of the largest fundraisers and product originators in the industry today.

2.1.4.3 1988 to Present - An Era of Solid Growth

The period from 1988 through to the present can best be characterized as a period of consistent growth of the industry. Assets under management, the number of advisors, and total employment in the industry all increased dramatically over the period. For example, assets under management for the industry jumped from $2.6 billion in 1988 to $44 billion in 1998 - a 17 fold increase in just 11 years. In 1988, there were no advisors managing $1 billion or larger funds, and only a handful managing $100 million or more. Today there are six advisors managing more than $1 billion and almost fifty managing more than $100 million.

Perhaps the most dramatic increase in interest in Managed Futures has been generated overseas. During this period, Japanese institutions have become large participants in the industry through the offering of Managed Futures in Japan. While Europe started showing interest in the early to mid-1980, the last ten years have seen a marked acceleration in their demand for Managed Futures products. Today there are approximately 35 advisors based in Europe alone.

Since the early 1990's, many international banks such as Credit Agricole Indosuez, Chase Manhattan, Citibank, Societe Generale, and Bank of America, have become active in developing and distributing Managed Futures products. In addition, Managed Futures are becoming more accepted by institutions. In the US, several public employee and corporate pension plans have opted to include Managed Futures in their portfolios. Some examples are: Virginia Retirement System, San Diego County Employees, ConRail, Intel, AMP, and the World Bank were all early institutional investors in Managed Futures.

The Managed Futures industry had, of course, also exhibited substantial growth during the 1980's. For example, from fewer than 15 publicly traded commodity funds in 1980 with less than US$500 million in total assets, the industry had grown by the end of 1991 to more than 200 public commodity funds and total assets under management, in all investment vehicles, to approximately US$21 billion. However, according to Cerrahogiu & Pancholi (2003), the rate of growth increased significantly throughout the following decade. They show that the dollars under management for Commodity Trading Advisors in the Managed Futures industry had grown from less than US$15 billion under management in 1990 to approximately US$37 billion in 2002.

This substantial growth occurred in spite of conflicting evidence regarding whether Managed Futures constituted an attractive stand-alone investment and/or an attractive addition to conventional portfolios consisting of stocks or bonds. Section 2.2 below provides more details regarding these research findings.

2.2 Review of the Evidence on the Performance of Managed Futures

This section will examine the main studies on Managed Futures funds' performance[3]. The analysis considers Managed Futures fund performance, as a stand-alone investment, as a portfolio asset (i.e., its impact on the risk/returns of a traditional well-diversified benchmark stock/bond portfolio) and in relation to an alternative investment, namely, hedge fund performance.

[3] Much of the reviews on Managed Futures funds' performance in this section here, except for Edwards & Liew (1999), were adopted and indirectly referenced from McCarthy (1995).

2.2.1 The Early Studies

Lintner (1983) is believed to be the first in the academic field to undertake a study on Managed Futures. He found that Managed Futures were attractive investment vehicles but later studies such as Elton, Gruber, and Rentzler (1987 and 1990) and Irwin, Krukemyer, and Zulauf (1992) found that Managed Futures, at least as represented by public commodity funds, did not generate returns above even the risk-free rate. Schneeweis, Savanayana, and McCarthy (1992) confirmed earlier results relative to public commodity funds, but limited the portfolio to 14 Commodity Trading Advisors.

Lintner (1983) examined the performance of 15 individual CTAs and 8 public commodity funds for the period July, 1979 through to December, 1982. In computing the returns for the 15 CTAs, Lintner (1983) used their composite performance (trading profits, including interest, net of all fees and commissions) as reported in their Disclosure Documents (reporting documents required by the Commodity Futures Trading Commission (CFTC)). This composite performance includes results from all accounts traded by the CTA, including public commodity funds, private pools, and individual managed accounts. As such, it offers a weighted return of the three different investment vehicles. Lintner also examined the monthly change in net asset value of 8 public commodity funds available to investors during the period he analysed.

As Table 2.1 shows, the average monthly standard deviation of individual CTAs in his study was 12.36%. Similar results were found for public commodity funds. However, Lintner also showed that diversifying an investment in Managed Futures by creating portfolios of CTAs substantially lowers the risk of an investment in Managed Futures. This results from the fact that the average correlation among the CTAs he examined was 0.285 (figures not provided in the Table).

Table 2.1: Key summary of descriptive statistics of Lintner, 1983, (compiled from McCarthy (1995)

	Mean returns (%)	Standard deviation of. Return (%)	Return/Risk Ratio
Average CTA	2.72	12.36	0.21
Minimum Risk Portfolio of CTAs	0.95	3.57	0.27
Average Public Commodity funds	2.03	9.58	0.24
Minimum Risk Portfolio of Commodity funds	2.01	5.02	0.4
Common Stocks	1.35	4.99	0.27
Corporate Bonds	0.67	5.21	0.13
Treasury Bills	0.94	0.19	4.85

Note: Period of Analysis: Monthly data from July 1979 to December 1982; returns are net of costs; Return to Risk ratio is Mean Monthly Return divided by Standard Deviation of Monthly Return.

As shown in Table 2.1, Lintner employed various techniques for creating the portfolios of CTAs, including equal allocation and minimum risk. Focusing on the minimum risk portfolio (row 2 of the Table 2.1), Lintner showed that creating portfolios of CTAs can lower the risk (as measured by standard deviation of monthly returns) of an investment in Managed Futures by as much as 71% (12.36 to 3.57%). The same effect can also be seen in the average versus the minimum risk portfolio of public commodity funds. The optimized minimum risk portfolio of public commodity funds has a standard deviation of 48% below that of the average public commodity fund (9.58 to 5.02).

In addition to their stand-alone risk/return characteristics, Lintner also analyzed the potential impact of adding Managed Futures to a portfolio of stocks (or stocks and bonds). First, Lintner established that both the CTAs and public commodity funds in his study had low correlations with both stocks and bonds. The various statistics are presented in the following page in table 2.2.

Table 2.2: Summary of statistics on correlation and breakeven returns for Managed Futures funds, from Lintner (1983), (compiled from McCarthy (1995)

	Mean	Standard deviation	Return/risk ratio	Correlation with stocks	Correlation with bonds	Breakeven returns vs stock	Breakeven returns/risk ratio vs bonds
Average CTA	2.72	12.36	0.21	NA	NA	NA	NA
Min risk portfolio of CTAs	0.95	3.57	0.27	-0.07	0.15	-0.02	0.02
Average public commodity funds	2.03	9.58	0.24	NA	NA	NA	NA
Minimum risk portfolio of public commodity funds	2.01	5.02	0.4	0.23	0.15	0.06	0.02
Stocks	1.35	4.99	0.27	1.00	0.42	NA	NA
Bonds	0.67	5.21	0.13	0.42	1.00	NA	NA
Treasury Bills	0.94	0.19	4.85	NA	NA	NA	NA

Note: Period of analysis: June 1979 to December 1982; analysis of: average of 15 individual CTAs; Minimum risk portfolio of 15 CTAs; average of 8 public commodity funds; Minimum risk public commodity fund.

For the minimum risk portfolio of CTAs, the correlation coefficient vs. stocks was –0.07 and vs. bonds was 0.15. For the minimum risk portfolio of public commodity funds it was 0.23 vs. stocks and 0.15 vs. bonds.

Lintner then examined whether adding sub-portfolios of Managed Futures to the portfolio of stocks (or stocks and bonds) improved the risk/return tradeoffs of those portfolios. For this analysis, Lintner employed the criteria that a security should be added to an existing portfolio when:

$$\theta_i > P_{ip}\theta_p \qquad (2.1)$$

where,

$\theta_i = R_i / \sigma_i$,

$\theta_p = R_p / \sigma_p$,

P_{ip} = Simple correlation between R_i and R_p,

R_i = Rate of return of security i,

R_p = Rate of return of portfolio p,

σ_i = Standard deviation of security i, and

σ_p = Standard deviation of portfolio p.

This framework states that a security i should be added to a benchmark portfolio p when adding it improves the ratio of return to risk of that portfolio. This occurs when the ratio of return to risk of security i, (R_i / σ_i) or θ_i is greater than the product of the ratio of return to risk of portfolio p, (R_p / σ_p) or θ_p and the simple correlation between security i and portfolio p, (P_{ip}). Therefore,

1) If the simple correlation is 1, security i must have a higher return to risk ratio than portfolio p for it to be an attractive addition.

2) If the correlation is –1, then security i must have a return to risk ratio greater than –1 time the return to risk ratio of portfolio p.

3) When correlation is zero, security i need only have a positive return to risk ratio to be added to the benchmark portfolio p.

This follows that whether or not Managed Futures are to be added to a portfolio of stocks or stocks and bonds is highly dependent on the correlation between Managed Futures and the alternative investment. Lintner found that these correlations to be low for both stocks and bonds.

A second analysis of Managed Futures was conducted by Elton, Gruber, and Rentzler (1987). Elton et al. (1987) examined the monthly performance of all public commodity funds in existence from June 1979. This included the 12 funds in 1979 and grew to 85 funds by 1985. This study extends the previous analysis by Lintner (1983) to include the time period from January 1983 to June 1985. This includes 12 funds in 1979 and grew to 85 funds by 1985. A summary of their key statistic are found in Table 2.3.

Table 2.3: Summary of key descriptive statistics, correlation and break-even returns of Elton, Gruber & Rentzler (1987), (compiled from McCarthy (1995)

	Mean holding period (% pa)	Standard deviation of Returns (%)	Breakeven Returns vs. Common stocks (%)	Breakeven Return Vs. Portfolio of common stocks and bonds (%)
Average Public commodity fund	-0.07	11.3	0.69	0.73
Common stocks	1.31	3.99	NA	NA
Government Bonds	0.75	4.35	NA	NA
Treasury Bills	0.85	0.15	NA	NA

Note: Period of analysis: monthly data from July 1979 to June 1985; Returns are net of all costs and are average monthly geometric rate of returns.

Elton et. al (1987) examined average monthly returns of public commodity funds and found that the average return (for an annual holding period) was –0.07% while their standard deviation was 11.3% per month. By comparison, common stocks had an average monthly return of 1.31% and a standard deviation of 3.99%, while long term government bonds had an average monthly return of 0.75% and a standard deviation of 4.35%. Based on the risk/return characteristics of the public commodity funds they analysed, Elton et. al. (1987) concluded that public funds were not a useful stand-alone investment. This conclusion was based on the fact that these funds had an overall negative return and were accompanied by average risk levels more than twice as high as stocks and bonds.

In addition to analysing whether public commodity funds were attractive stand-alone investments, Elton et. al. (1987) examined whether public commodity funds could be advantageously added to a portfolio of stocks and bonds. To address this issue, they employed the framework developed in Elton, Gruber, and Padberg (1976). In this formulation they showed that a security should enter an optimal portfolio when its risk adjusted excess return exceeds the product of the risk adjusted excess return of the market portfolio and the correlation coefficient of the security being considered.

Equation (2.2) below is very similar to the framework utilized by Lintner (1983) and presented in Equation (2.1). The only difference is that Equation (2.1) looked at the ratio of return to risk without consideration of the risk free rate while Equation (2.2) measures the ratio of excess return to risk where excess return is defined as return minus the risk free rate. The latter framework is generally known as Sharpe Ratio. The Sharpe Ratio, a measure of the ratio of excess return to risk, is used to compare assets with varied return and risk characteristics. It is presented as:

$$\frac{R_c - R_f}{\sigma_c} > \left(\frac{R_p - R_f}{\sigma_p}\right) P_{cp} \qquad (2.2)$$

where,

R_c = the expected return of the security being examined,

R_f = the risk-less rate,

σ_c = the standard deviation of the security being examined,

R_p = the expected return of the portfolio,

σ_p = the standard deviation of the portfolio, and

P_{cp} = the correlation coefficient between the security and the portfolio.

Higher Sharpe ratios correspond to a more positive excess return to risk trade-off. When presented on a graph, the return will be plotted on the vertical axis and risk on the horizontal axis, the Sharpe Ratio then represents the slope of the line connecting the risk free rate on the vertical axis to security i plotted in return/risk space with coordinates (R_c, σ_c). In this representation, portfolio 2 dominates portfolio 1 at all levels of risk except at the Y axis where all portfolios would hold the risk-less investments. The following shows the graphical representation of the Sharpe Ratio, where $E(R_p)$ denotes the expected return of portfolio p and σ_p is its standard deviation.

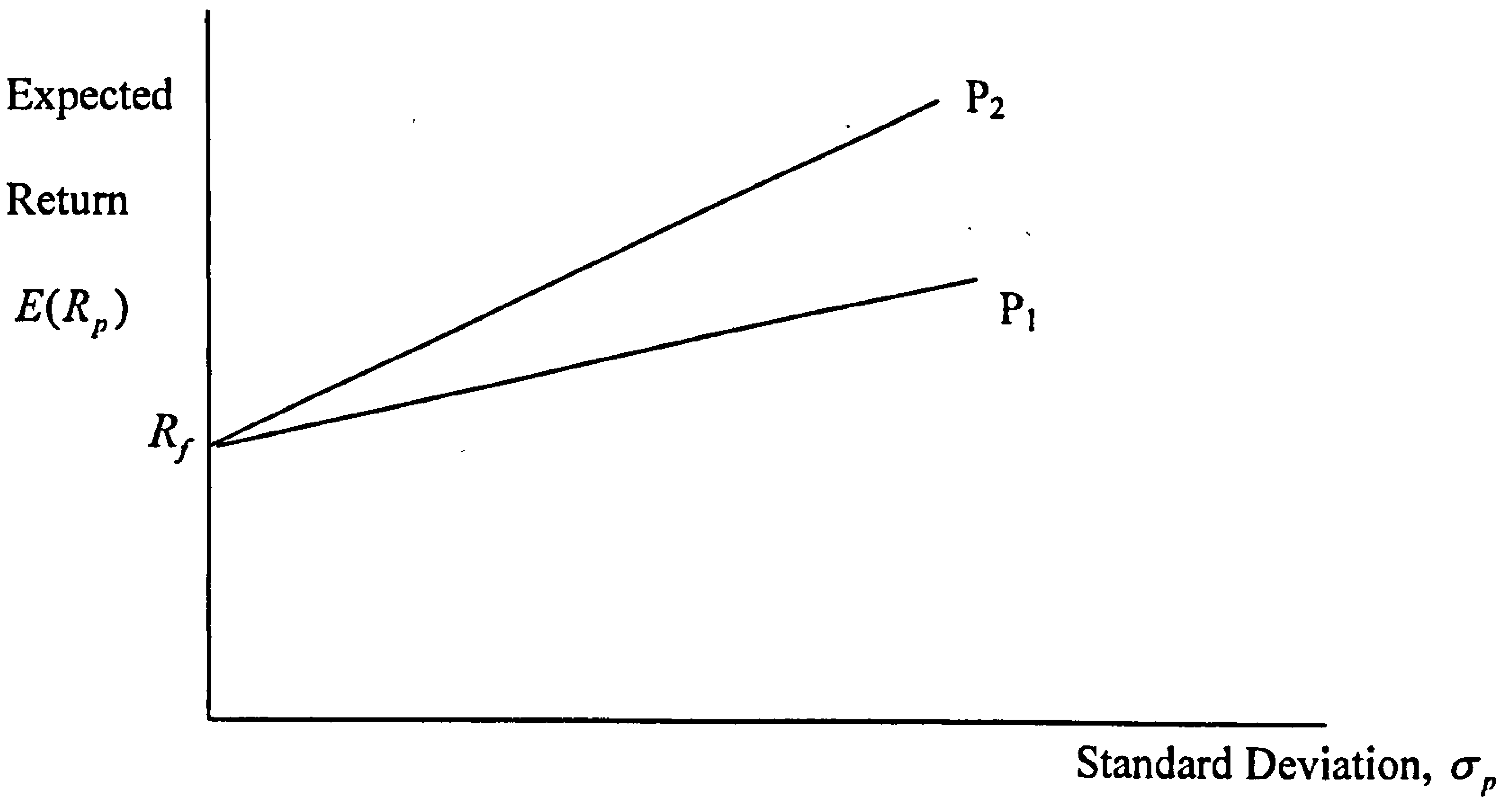


Figure 2.1: Graphical Representation of Sharpe Ratio

Elton et al. (1987) point out that the formulation in equation 2.2 essentially states that the Sharpe Ratio of the security being examined (the left-hand-side of Equation 2.2) must exceed the product of the Sharpe Ratio of the market portfolio and the correlation coefficient between the security and the portfolio. To the extent that it is greater, then adding a weighting of the security to the portfolio will improve the risk/return characteristics of the portfolio by shifting the efficient frontier up or to the left as shown above.

To examine whether public commodity funds should be added to a stock (or stock and bond) portfolio, Elton et al. (1987) first examined the correlation coefficients between the public commodity funds and stocks and bonds. They found that the correlation coefficient between pubic commodity funds and stocks was only –0.121, while for bonds it was –0.003. These low correlations, which are not presented in our Tables, were consistent with Lintner's earlier study. Then, solving for the breakeven rate of return required from public commodity funds in order for it to be added to portfolios of stocks (or stocks and bonds), Elton et. al. (1987) estimated that an average monthly return for public commodity funds of approximately 0.69% would be required, with a weight of 63%, and bonds with a weight of 37%. These break-even returns are presented in Table 2.3 and can be compared to the actual return of the average public commodity fund. As can be seen from the table, the mean monthly return of the average public commodity fund (-0.07%) is considerably below the breakeven level required for inclusion in a portfolio of stocks (0.69%) or in stocks and bonds (0.73%). Elton et al. (1987) concluded that public commodity funds do not constitute attractive additions to portfolios of stocks (or stocks and bonds).

In a later analysis of this issue, Elton, Gruber, and Rentzler (1990) re-examined the performance of public commodity funds using data from 1980 through 1988. Their analysis showed that while the average return of public commodity funds had improved to 2.3% p.a.

this time, this return was still substantially below the risk free rate. This, together with the continuing high risk level of public commodity funds (monthly standard deviation of 10.4%), led them to affirm their earlier conclusion that public commodity funds did not offer an attractive investment opportunity.

Irwin, Krukemyer, and Zulauf (1992) also addressed the issue of whether public commodity funds are good investments, examining all public commodity funds available during the period January 1979 through December 1989. Their results are summarized in Table 2.4 below.

Table 2.4 - Summary of descriptive statistics, correlation and breakeven returns of Irwin, Krukemyer, and Zulauf (1992) (compiled from McCarthy (1995)

	Mean holding period returns (%)	Standard deviation of returns (%)	Correlation vs common stocks	Correlation vs LT Govt Bonds	Breakeven Returns vs Common Stock (%)	Breakeven Returns vs Portfolio of stocks and bonds (%)
RS commodity fund	0.59	9.97	0.09	0.05	0.84	0.86
EW portfolio of commodity fund	0.91	6.68	NA	NA	0.85	0.85
Common stocks	1.36	4.65	NA	NA	NA	NA
Long term government Bonds	0.89	4.02	NA	NA	NA	NA
Treasury bills	0.72	0.23	NA	NA	NA	NA

Note: Period of Analysis: Monthly data from January 1979 to December 1989; Returns are net of all costs and are average monthly geometric rates of returns; RS means 'Randomly Selected'; EW means 'Equally weighted'.

In their analysis, Irwin et. al (1992) examined performance from the standpoint of a single randomly selected public commodity fund - a portfolio of all public commodity funds over the same period.

Irwin et. al's (1992) analysis focused on monthly rates of return based on an annual holding period. Their results, summarised in Table 2.4, indicate that a randomly selected public commodity fund had a lower return (0.59%) and higher monthly standard deviation (9.97%) than investments in stocks (1.36% and 4.65%) or long term government bonds (0.89% and 4.02%). Further, the return of a randomly selected fund was less than the risk free rate (0.72%) over the same period. Irwin et. al. (1992) also considered two sub-periods subsequently, 1982-89 and 1985-89, and shows that in neither sub-period did the rate of return of a randomly selected fund exceed the risk free rate.

Analysis of an equally-weighted investment in a portfolio of public commodity funds typically, however, performed better than a randomly selected fund. Irwin et.al (1992) showed that over the entire 1979 to 1989 time period, the average monthly return from an investment in this portfolio was 0.91% with a standard deviation of 6.68%. This return exceeds the risk free rate (0.72%) and compared to a randomly selected fund, demonstrated a reduction in risk as measured by the monthly standard deviation (9.97% to 6.68%). The return on this portfolio of public commodity funds was lower than for either common stocks but higher than for bonds over the same time period (0.91% vs. 1.36% for stocks and 0.89% for bonds), and its risk, while lower than the randomly selected fund, was still greater than that of stocks and bonds (6.68% vs. 4.65% for stocks and 4.02% for bonds). Further, in one sub-period (this one sub-period result is not presented in our section) examined, 1982 to 1989, the portfolio of funds demonstrated a worst performance than the risk free rate (0.4% vs. 0.64%) and in the other sub-period, 1985 to 1989, was only marginally better than the risk free rate (0.57% vs. 0.55%).

Irwin et.al. (1992) also addressed the issue of whether public commodity funds make attractive additions to portfolios of stocks or diversified portfolios containing 60% stocks and 40% bonds. Following the same analytic procedures used by Elton, Gruber, and Rentzler (1987), Irwin et.al (1992) found that the randomly selected public commodity fund had a lower monthly return than the required breakdown for addition to portfolios of stocks, or stocks and bonds. However, the results for the market portfolio of funds were more ambiguous. While the monthly return for the equally weighted market (0.91%) portfolio of funds exceeded its breakeven rate vs. stocks (0.85%) and vs. a portfolio of stocks and bonds (0.85%) for the full time period (shown in Table 2.4), the monthly returns of the randomly selected market portfolio (0.59%), however, were lower than the breakeven level of the portfolio of stocks (0.84%) and that of the portfolio of stocks and bonds (0.86%).

2.2.2 The Most Recent Studies

Using a more comprehensive set of data and extending to a wider time periods, Edwards & Liew (1999) examined the monthly performance of CTAs, private pools, and public funds over the period from 1980 to 1996. Unlike all the previous studies, this research encompasses 1150 CTAs, 439 private commodity pools and 619 public futures funds, for a total of 119481 months of performance data: 60054 for CTA's, 24523 for commodity pools, and 34904 for public funds. These data are provided by Managed

Account Reports (MAR), which receives monthly performance information from participating CTAs, pools and funds[4].

Similar to earlier research by Lintner (1983) and Elton, Gruber, and Rentzler (1987 and 1990), Edward & Liew (1999) evaluate the performance of alternative Managed Futures investments based on three stylized Managed Futures portfolios formed for CTAs, pool and funds. They are: 1) one-CTA, pool or fund portfolios, where a single CTA, pool or fund randomly selected. 2) An equally-weighted market portfolio (EWMP) of all CTAs, pools or funds in existence in a particular month, where an identical amount is invested in each CTA, pool or fund; and, 3) A value-weighted portfolios (VWMP) of all CTAs, pool or fund in existence in a particular month, where the weights reflect the proportion of total invested dollars managed by particular CTAs, pools or funds in the month. Monthly and yearly returns are then computed for each of these stylized portfolios.

In assessing the performance of these CTAs, pool and funds, unlike all other previous literatures that we reviewed, Edwards & Liew (1999) use the Sharpe Ratio ranking approach. To do that, Edwards & Liew (1999) break the periods down into 1982 to 1988 and 1989 to 1996. Table 2.5 from Edwards & Liew (1999), shown in the following page, provides a summary of their Sharpe Ratio ranking results. The results shown in Table 2.5 have 4 major implications. Firstly, a VWMP of pools stands out as an attractive stand-alone investment, with respect to both alternative non-futures investments and other Managed Futures investments, especially during the 1989 to 1996 period. Although a VWMP of

[4] Notably, there are 'self-selection' and 'survivorship bias' found in those data-set, see Chapter 3, under section on 'limitation of data' for more explanation.

***Table 2.5 Summary of statistics* on comparison of Sharpe Ratio, Ranking by Sharpe Ratio and Average Annual Returns, 1982 - 1996 (from Table 5 of Edwards & Liew (1999)) (12-Month rule for CTAs, 5-month rule for commodity pools and 6-month rule for commodity funds)**

	1982:1 - 1996:12			1982:1 - 1988:12			1989:1 - 1996:12		
	Sharpe Ratio	Sharpe Ratio Rank	Average Annual Returns	Sharpe Ratio	Sharpe Ratio Rank	Average Annual Returns	Sharpe Ratio	Sharpe Ratio Rank	Average Annual Returns
Equally-Weighted Market Portfolios									
RS CTAs	0.421	8	23.20%	0.407	7	34.30%	0.274	8	13.30%
RS Private Pools	0.346	9	18.40%	0.406	8	28.70%	0.152	9	9.40%
RS Public Funds	0.112	11	9.80%	0.155	11	14.00%	0.035	11	6.20%
EW CTAs	0.977	1	23.20%	1.196	1	34.30%	0.796	2	13.30%
EW Private Pools	0.662	5	18.40%	0.894	2	28.70%	0.371	7	9.40%
EW Public Funds	0.211	10	9.90%	0.303	10	14.10%	0.088	10	6.20%
S&P 500 (large cap)	0.717	4	16.70%	0.581	6	17.50%	0.912	1	16.00%
Long-term Corporate Bonds	0.806	2	13.20%	0.867	4	16.50%	0.777	3	10.20%
Intermediate-term Govt bonds	0.775	3	10.40%	0.869	3	12.70%	0.689	4	8.40%
Long-term Government Bonds	0.657	6	13.10%	0.667	5	15.70%	0.67	5	10.80%
Russell 2000 (small cap)	0.451	7	14.40%	0.339	9	14.60%	0.597	6	14.20%
Value-Weighted Market Portfolios									
RS CTAs	0.421	8	23.20%	0.407	7	34.30%	0.274	8	13.40%
RS Private Pools	0.346	9	18.40%	0.406	8	28.70%	0.152	10	9.40%
RS Public Funds	0.112	11	9.90%	0.155	10	14.10%	0.035	11	6.20%
VW CTAs	0.422	7	13.80%	0.465	6	18.00%	0.399	7	10.10%
VW Private Pools	0.752	3	16.70%	0.694	3	19.80%	0.955	1	13.90%
VW Public Funds	0.142	10	8.60%	0.116	11	10.10%	0.202	9	7.60%
S&P 500 (large cap)	0.717	4	16.70%	0.581	5	17.50%	0.912	2	16.00%
Long-term Corporate bonds	0.806	1	13.20%	0.867	2	16.50%	0.777	3	10.20%
Intermediate-term Govt bonds	0.775	2	10.40%	0.869	1	12.70%	0.689	4	8.40%
Long-term Government Bonds	0.657	5	13.10%	0.667	4	15.70%	0.67	5	10.80%
Russell 2000 (small cap)	0.451	6	14.40%	0.339	9	14.60%	0.597	6	14.20%

RS: Randomly-Selected single-CTA, pool or fund portfolios
EW: Equally weighted market portfolio. VW: Value-weighted market portfolio
Annual Sharpe Ratios are computed from monthly observations by multiplying the monthly Sharpe ratio by the square root of 12
Average Annual returns are the average monthly returns multiplied by 12

of pools earned a somewhat lower average annual return than common stock during this period (13.9% compared with 16.0%), the lower volatility of pool returns, however, has resulted in a higher Sharpe ratio for the VWMP of pools of 0.955. This performance is especially impressive given the extraordinary high common stock returns during the 1989 to 1996 period. A clear implication is that private pool managers add value: they generate returns and higher Sharpe ratios than most non-futures investments do, and they outperform other Managed Futures returns.

Secondly, neither single-CTA, pool, fund portfolios nor any type of public fund investment appear to make an attractive stand-alone investment. Single-CTA, pool or fund portfolios all have high return volatility, and public funds have low returns. Thirdly, the strong performance of a EWMP of CTAs during the 1982-1988 periods should probably be given less credibility for two reasons. According to Edwards & Liew (1998), this period is subjected to the greatest survivorship bias[5], and CTA reported returns are highly sensitive to the exclusion rule used to control for self-selection bias.

Fourthly, returns on all types of Managed Futures investments fell substantially in 1989 to 1996, compared to 1982 to 1988, for reasons that remain unclear. A possible "data" explanation, according to Edwards & Liew (1998), is that returns in 1982 to 1988 periods may have been artificially inflated because of an upward survivorship bias6, so that the elimination of this bias in the 1989 to 1996 period makes it appear that returns fell in 1989 to 1996. Another possibility is that market condition from 1989 to 1996 may not have not been favourable to commodity traders. In particular, most commodity traders are in a

[5] See footnote 2.
[6] See footnote 2.

greater or lesser degree "trend followers", and in 1989 to 1996, commodity prices have appeared to exhibit less trend following behaviour than in earlier years, making it difficult for traders to identify price trends and to capitalise on such trends. Finally, during 1989 to 1996, there was undoubtedly greater competition. With a greater number of traders and more capital competing for trading profits, commodity markets may have become more efficient, resulting in lower returns.

Fifthly, despite the decline in the level of returns in 1989 to 1996, the Sharpe Ratio for a VWMP of pools rose significantly from 1982-1988 to 1989-1996 (from 0.694 to 0.9555) – lower returns were more than offset by a lower volatility of returns. However, this appears not true for a EWMP of pools or for either a EWMP or a VWMP of CTAs. Thus, large pools appear to have been more successful in managing risk than were either small pools or individual CTA.

Edward & Liew (1999) also provide an alternative way to view managed commodity funds as a separate asset class in a diversified portfolio, and then determine whether portfolio performance is significantly enhanced by the inclusion of commodity funds in the portfolio.

Table 2.6, following this page, from Edward & Liew (1999) shows the simple correlation coefficients between managed commodity fund returns and the returns on other asset classes. In general, these correlations are very low (generally below 0.10) and are often not significantly different from zero. Some correlations are even negative. For example, returns on a VWMP of pools are negatively correlated with S&P 500 common

Table 2.6: Summary of statistics on correlation coefficient for 1982-1996 and sub-periods 1982-1988 and 1989-1996 from Table 6 of Edwards & Liew (1999))

(12-Month rule for CTAs, 5-month rule for commodity pools and 6-month rule for commodity funds)

1982:1-1996:12	EW CTAs	EW Pools	EW Funds	VW CTAs	VW Pools	VW Funds	Common Stocks	Long Corporate Bonds	Inter Govt Bonds	Long Govt Bonds	T-Bills	Small Cap Stocks
EW CTAs	1											
EW Private Pools	0.93**	1										
EW Public Funds	0.90**	0.89**	1									
VW CTAs	0.91**	0.91*	0.95**	1								
VW Private Pools	0.84**	0.86**	0.82**	0.90**	1							
VW Public Funds	0.89**	0.86**	0.96**	0.96**	0.87**	1						
Common Stk Rtns (S&P)	-0.01	-0.03	0.08	0.02	-0.05	0.08	1					
L-T Corporate Bonds	0.07	0.07	0.06	0.06	0.09	0.09	0.40**	1				
Inter-T Govt bonds	0.04	0.03	0.05	0.03	0.04	0.08	0.34**	0.92**	1			
L-T Govt Bonds	0.11	0.09	0.11	0.1	0.14*	0.15*	0.39**	0.94**	0.92**	1		
Treasury Bills	0.09	0.09	0.05	0.04	0.06	0.02	-0.02	0.18**	0.23**	0.14*	1	
Russell 2000	-0.08	-0.1	-0.02	-0.06	-0.13	-0.03	0.85**	0.22**	0.15*	0.19**	-0.1	1

Sub-periods 82:1 - 88:12 \ 89:1 - 96:12	EW CTAs	EW Pools	EW Funds	VW CTAs	VW Pools	VW Funds	Common Stocks	Long Corporate Bonds	Inter Govt Bonds	Long Govt Bonds	T-Bills	Small Cap Stocks
EW CTAs	1	0.96**	0.92**	0.96**	0.84**	0.91**	-0.02	0.15	0.14	0.16	0.14	-0.20**
EW Private Pools	0.92**	1	0.92**	0.94**	0.90**	0.89**	0.01	0.19*	0.16	0.21**	0.1	-0.16
EW Public Funds	0.91**	0.89**	1	0.96**	0.77**	0.97**	0.12	0.21**	0.21**	0.23**	0.08	-0.11
VW CTAs	0.91**	0.90**	0.94**	1	0.83**	0.95**	0.01	0.18*	0.17*	0.20**	0.05	-0.16
VW Private Pools	0.85**	0.85**	0.83**	0.92**	1	0.76**	-0.11	0.11	0.1	0.15	0.15	-0.26**
VW Public Funds	0.90**	0.86**	0.96**	0.97**	0.91**	1	0.14	0.25**	0.25**	0.27**	0.04	-0.1
Common Stk Rtns (S&P)	-0.01	-0.06	0.06	0.03	-0.02	0.06	1	0.52**	0.43**	0.49**	0.08	0.77**
Long term Corporate Bonds	0.03	0.01	0	0.01	0.07	0.03	0.34**	1	0.92**	0.98**	0.12	0.24**
Inter-term Govt Bonds	-0.03	-0.05	-0.03	-0.05	0.01	0	0.29**	0.93**	1	0.92**	0.17*	0.12
Long term Goverment Bonds	0.08	0.04	0.06	0.05	0.13	0.1	0.33**	0.92**	0.92**	1	0.1	0.19*
Treasury Bills	-0.06	-0.03	-0.02	-0.02	-0.02	0	-0.12	0.16	0.22**	0.13	1	-0.08
Russell 2000	-0.05	-0.08	0.02	-0.01	-0.08	0	0.89**	0.22**	0.16	0.19*	-0.14	1

Correlation computed using monthly returns.
EW: Equally weighted Mkt Portfolio; VW: Value-weighted market portfolio:
Test Statistic: t (n-2) = r/ (1-r^2)/ (n-2) ^0.5.
For 82-96, the critical values at the 5% and 10% level are 1.9759 and 1.6551 respectively; for 82 - 88, they are 1.9886 & 1.6632 respectively and for 89-96, they are 5% and 10% level are 1.985 and 1.6609.
*Significant at the 10%; **at 5%

stock returns in all time periods, although they are never significantly different from zero. The highest correlation observed for the 1982-96 period is 0.15, between a VWMP of funds and long-term government bonds. Thus, including managed commodity funds in a diversified asset portfolio should provide diversification benefits.

Table 2.6 provides the "break-even" returns for the alternative commodity fund investments. Specifically, the minimum (or "break-even") rate of return that a commodity fund must earn in order to enhance portfolio performance can be determined by rewriting equation (2.2) and solving for R_c, the required rate of return, with the equation specified as follows:

$$\left[\frac{R_c - R_f}{\sigma_c}\right] \geq \rho_{pc}\left[\frac{R_p - R_f}{\sigma_p}\right], \qquad (2.3)$$

$$R_c \geq \rho_{pc}\left[\frac{\sigma_c}{\sigma_p}\right](R_p - R_f) + R_f,$$

where R_c= the average monthly rate of return on commodity fund investment c; R_f = the average monthly risk-less rate of return; σ_c= the standard deviation of monthly rates of return on commodity fund investment c; R_p= the average monthly rate of return on portfolio p, σ_p = the standard deviation of the monthly rates of return on portfolio p; and ρ_{cp} = the simple correlation between monthly returns on the commodity fund investment c and monthly returns on portfolio p. For given σ_c, ρ_{cp}, σ_p, R_p and R_f, therefore, the required rate of return on a commodity fund investment is R_c.

Break-even returns for two hypothetical portfolios are shown in Table 2.7: one is 100 percent invested in the S&P 500 common stock index, and the other consists of 60 percent S&P 500 stocks and 40 percent long-term corporate bonds. Also shown are actual returns on the alternative commodity fund investments. If the actual return on a commodity fund investment is greater than the break-even return for that investment, including the investment in a diversified portfolio will raise the portfolio's Sharpe ratio.

Table 2.7 Summary of break-even analysis from table 7 of Edwards & Liew (1999)
(12-month rule for CTAs, 5-month rule for commodity pools and 6-month rule for commodity funds)

		1982:1 - 1996:12		1982:1 - 1988:12		1989:1 - 1996:12	
		100% Stock	60% Stocks 40% Bonds	100% Stock	60% Stocks 40% Bonds	100% Stock	60% Stocks 40% Bonds
EW CTAs	Break-even return	6.16%	6.51%	7.38%	7.52%	5.03%	5.49%
	Average return	23.16%	23.16%	34.32%	34.32%	13.32%	13.32%
VW CTAs	Break-even return	6.63%	6.92%	7.93%	8.01%	5.37%	5.99%
	Average return	13.80%	13.80%	18.00%	18.00%	10.08%	10.08%
EW Pool	Break-even return	5.86%	6.23%	6.77%	6.76%	5.37%	5.95%
	Average return	18.36%	18.36%	28.68%	28.72%	9.36%	9.36%
VW Pool	Break-even return	5.85%	6.20%	7.34%	7.64%	4.29%	4.71%
	Average return	16.68%	16.68%	19.80%	19.80%	13.92%	13.92%
EW Funds	Break-even return	7.25%	7.53%	8.27%	8.35%	6.51%	7.05%
	Average return	9.84%	9.84%	14.04%	14.04%	6.24%	6.24%
VW Funds	Break-even return	7.27%	7.67%	8.24%	8.48%	6.66%	7.29%
	Average return	8.64%	8.64%	10.08%	10.08%	7.56%	7.56%

Notes: EW: equally-weighted market portfolio; VW: value-weighted market portfolio.
Stock: S&P 500 (large cap); Bonds: Long-Term corporate bonds.

Over the entire 1982-96 period, as well as for the sub-period 1982-88, all commodity fund investments satisfy this criterion for both benchmark portfolios. The only exception occurs in 1989-96, when a EWMP of public funds fails to satisfy this criterion for either benchmark portfolio.

A VWMP of public funds barely satisfies it. Thus, a break-even analysis indicates that including commodity fund investments in diversified stock and bond portfolios will enhance the performance of those portfolios.

2.2.3 Comparison of Managed Futures with Hedge Funds as Effective Portfolio Diversifiers

The effectiveness of Managed Futures as a potential diversifier is an important issue since a significant component of our research focuses on the benefits of Managed Futures when used within an already diversified UK stock/bond portfolio. In this section, we undertake a comparison of the literatures and findings relating to hedge funds and Managed Futures regarding their respective effectiveness as potential portfolio diversifiers. As Hedge funds are the most widely used alternative investment instrument in the industry, findings on the effectiveness of Managed Futures as a diversifier arising from comparison with hedge funds will therefore be of significant importance to academics and practitioners alike.

The use of financial/commodities futures as a form of asset class is perhaps most beneficial and/or viable during volatile market conditions. For example, Karim, A (2001) (2001) explains that in recent years, Managed Futures have on average delivered modest returns. Though this might have disappointed investors, the contribution from using Managed Futures in a portfolio context stems from the fact that when traditional investments are performing well, Managed Futures strategies also still perform, even if modestly. During bad times for traditional investments, however, Managed Futures appear to continue to provide essential protection for other asset classes in the portfolio. This makes an investment in Managed Futures a true hedge (though using Managed Futures in this context is really as an 'asset class' and not as a form of 'hedge') for a portfolio manager. Purely from the return point of view, the 'cost' of this hedge may be the foregone opportunity of greater performance from alternative strategies. But the gains can come from the large downside risk reduction associated with strategies that involve Managed Futures being included in the portfolio.

Edwards and Caglayan (2001) state that the primary motivation for investing in hedge funds and commodity futures funds is to diversify the risk associated with falling stock prices. They then carried out relative performance tests on 16 funds during rising and falling stock market periods between 1990 and 1998 and evaluated them both as stand-alone assets and as portfolio assets. Edwards and Caglayan (2001) found that commodity funds generally provided more downside protection than hedge funds. Commodity futures funds had higher returns in bear markets than hedge funds, and generally had an inverse correlation with stock returns in bear markets. Hedge funds in contrast typically exhibited a higher positive correlation with stock returns in bear markets than in bull markets.

Kat (2002) used a wider range of monthly data from June 1994 to May 2001, aimed at studying the possible role of Managed Futures in portfolios of stocks, bonds and hedge funds. He found that allocations to Managed Futures allowed investors to achieve a very substantial degree of overall risk reduction at limited cost. Apart from their lower expected return, Managed Futures appeared to be more effective diversifiers than hedge funds. Adding Managed Futures to a portfolio of stocks and bonds tended to reduce the portfolio standard deviation by more and quicker than an equivalent hedge fund investment, and without the undesirable side-effects of skewness and kurtosis, i.e., positive skewness is still possible in portfolios with a certain proportion of Managed Futures. This after all increases the case for the use of Managed Futures as an effective diversifier. Kat (2002) also found that the overall portfolio standard deviation could be reduced further by combining both hedge funds and Managed Futures with stocks and bonds. However, as long as at least 45-50% of the alternatives allocation is in Managed Futures, this will not typically have any negative side effects on the skewness and/or kurtosis of the portfolio. These results confirm the likely effectiveness of Managed Futures as a choice diversifier within a portfolio.

2.4 Concluding Remarks

This chapter has reviewed the development of the (largely US based) Managed Futures industry and the literature on the performance of Managed Futures, both as a stand-alone investment, and as part of a traditional stock/bond portfolio. The literature has revealed that there is conflicting evidence regarding the different types of Managed Futures funds and their respective historical performance. However, all of the literature reviewed have indicated that Managed Futures are generally lowly correlated with traditional stocks and bonds. The literature is therefore supportive of the use of Managed Futures as a basic diversifier within a traditional stock/bond portfolio, i.e., there are potentially incremental risk-reduction benefits relative to portfolios that contain solely stock/bond assets. This then provides an important role for Managed Futures for US investors, as well as for investors outside of the US.

Furthermore, the empirical findings on the effectiveness of using Managed Futures, as compared to hedge funds as potential portfolio diversifiers found in Edwards and Caglayan (2001) and Kat (2002), also suggests that research to assess the viability of using Managed Futures as part of an internationally diversified UK portfolio may reveal similar beneficial possibilities.

The rationale and purpose of the research of this thesis is also supported by Oberuc (1992), whose study focused on the performance of Managed Futures outside the United States. Oberuc's (1992) research is an important study in regard to our research since it indicates potential benefits to the non-US (particularly European) investor and practitioner communities from Managed Futures investments.

Oberuc (1992) analysed the effect of using Managed Futures in combination with a number of non-US investment portfolios in 4 European countries over the period from 1979 to 1989. The countries selected were the UK, Germany, France and Switzerland. Oberuc's (1992) findings revealed that these portfolios, whether or not they use currency-hedged or unhedged Managed Futures, seemed to perform significantly better (i.e., higher return given the same level of risk) than those portfolios that did not include Managed Futures. However, Oberuc's (1992) study also shows that there are wide variations in the relative (hedged and unhedged) performance across countries where CTAs are used as part of their stock/bond portfolio. There are also differences across time periods. These international and inter-temporal differences in the hedged and unhedged returns of CTAs seem to arise mainly from the relative appreciation or depreciation of the US dollar against these individual countries' currencies in the relevant time period.

Oberuc (1992) shows that measuring and analysing performance from a European or off shore (assuming US Dollar based Managed Futures funds are the most widely available funds) perspective is different from analysing the issue from a US investor's perspective. This is especially the case concerning the issue of exchange rate movements. As the research of this thesis is more focused towards analysing off-shore US Dollar based Managed Futures from the point of view of UK investors, foreign exchange movements and conversion issues naturally become important.

In investigating the role of US Dollar based Managed Futures from a UK investor perspective, exchange rate issues and how their movements can further be exploited to enhance UK portfolio returns, will be considered. This analysis is undertaken in Chapter 3, which, at the same time, also describes the data sources, provides a discussion of methodologies and the limitation/treatment of exchange rate conversions and movements. Hence, the purpose of Chapter 3 is to set up the structure for the subsequent empirical chapters (4, 5 and 6).

Chapter 3

Empirical Research Questions, Methods and Data Sources

3.0 Introduction to the Chapter

This chapter contains a description of the data and empirical methods adopted for the analyses of the benefits of Managed Futures to UK investors undertaken in Chapters 4 to 6. The primary purpose of this chapter is however to provide a discussion of the main issues the research addresses and the academic rationale(s) underlying the types of analyses undertaken in subsequent chapters. The chapter is structured as follows: firstly, the underlying rationale and motivation of the research is explained. This is then followed by a description of the general approach of the research. The discussion includes issues relating to the treatment of currency conversion required in order to calculate the returns achievable by UK investors, and the limitations of the data that are used in the empirical analyses in later chapters.

3.1 The Rationale and Intuition of the Research

In the previous chapter, it will be recalled that the empirical evidence in respect of the performance of Managed Futures suggested that, due to the low correlation with the returns of other asset classes such as stocks and bonds, allocating some positive proportion of investment funds to Managed Futures could, in principle, result in significant incremental portfolio risk reduction or enhanced return outcomes. It will, however, also be recalled that this "evidence" consisted largely of US based studies on Managed Futures investments. Naturally, as the current research focuses on the returns from Managed Futures achievable by UK investors, it would have been helpful if the UK had its own Managed Futures industry. Unfortunately, the UK does not at present have a significant regulated Managed Futures industry and, therefore, the lack of UK studies on the subject is understandable. This also implies that the conventional 'compare and contrast' type of analysis between the UK and US-based Managed Futures, similar to analyses that have, for example, compared and contrasted UK and US pension and mutual funds, is not possible.

Though the UK lacks an established and regulated Managed Futures retail market of its own, UK investors are, in principle at least, able to gain exposure to the 'off-shore', US-dollar based Managed Futures funds. However, in the UK, this exposure tends to be restricted in practice to high net worth clients and (increasingly) institutional investors. In the US there are relatively few such restrictions on the selling of Managed Futures products to retail investors. The cost of these public policy constraints on UK investor choice sets may, therefore, be estimated as the foregone incremental returns and/or risk reduction opportunities associated with having the option of investing some portion of their portfolios in Managed Futures products.

In order to estimate the potential incremental benefits to UK investors associated with access to US dollar based Managed Futures products, the research has to determine a method of simulating and analyzing these incremental benefits in terms of UK investor returns. This research explores three different approaches to ascertain the benefits of using US dollar based off shore Managed Futures within a UK portfolio. To date there has not been much research on Managed Futures that has used these three approaches, none of which has been applied to the UK. Basically, the portfolio allocation benefits to UK investors associated with using US-dollar-based Managed Futures are examined using the following allocation mechanisms:

1) within a downside risk based optimization framework (Chapter 4),
2) using a time-varying variance optimization framework (Chapter 5) and,
3) within an active currency management framework (Chapter 6).

The background and detailed literature review that relates to each of the allocation mechanisms will be discussed in the relevant chapter concerned. The three allocation mechanisms address the same basic issue, namely how to evaluate the potential benefits of including US-dollar Managed Futures within a typical well-diversified UK investor portfolio. Nevertheless, it was decided not to devote a whole chapter to a detailed discussion of the literature associated with these three allocation mechanisms, because each involves a very distinctive set of issues and much of the same material would need to be repeated in the introductions of each of the empirical chapters.

Prior to examining the above three allocation methods, a more immediate issue is to consider an appropriate approach to issues such as currency conversion and the availability and use of data sources and its limitations. The next section explains the choice of research methods and our data sources and its limitations.

3.2 The Research Framework, Empirical Method and Data Used

3.2.1 Data Used

3.2.1.1 Data Source

In order to carry out meaningful empirical research into the performance of Managed Futures and the potential benefits to UK investors, a suitable dataset is required. Due to their greater availability, all our empirical analyses use portfolios that consist of only equities, stock indexes, and Managed Futures. This inevitably means that there are no bonds, bond indexes or cash investments included in the benchmark portfolios.

Investment texts and surveys of fund management practices strongly suggest that in practice portfolio construction involves (at least) a two stage process. The first stage is the tactical asset allocation decision, which determines the proportions of the portfolio to be invested in various asset classes, e.g., equities, bonds and cash. The second stage of portfolio construction is "security selection", i.e., the choice of which individual securities to hold within each asset class. This empirical research deals exclusively with the first stage, the asset allocation decision, and therefore does not involve any security selection issues. The lack of any security selection requirement simplifies the calculation of benchmark equity returns since the returns of a value-weighted index of widely-held and liquid corporate securities can be expected to provide a close proxy to the average equity returns achievable by investors. Hence, for convenience and ease of replication, index based monthly data, rather than the underlying company or CTA performance data, are chosen.

All the Managed Futures indexes used in this thesis have been downloaded from MarHedge, www.marhedge.com, and the equity portfolio performance measures are based on the MSCI indexes obtained from Data-stream International. Table 3.1(A) provides a description of the various types of "Commodity Trading Advisor" (CTA) whose performance is incorporated in the MarHedge indexes. These CTA indexes are: Trend-Following CTA, Discretionary CTA, Diversified CTA, Currency CTA, Financial CTA and The Managed Account Research's "Trading Advisor Qualified Universe" (MAR) index. Table 3.1(B) shows the type of futures contracts most commonly traded by these CTAs. The index data used for Managed Futures are net of fund manager's performance fees, while the data for stock indexes are price data of MSCI stock indexes.

The various MSCI stock indexes used in the thesis are: MSCI Canada stock index, MSCI France index, MSCI Germany index, MSCI Japan index, MSCI Switzerland index, MSCI US index, MSCI UK index and the MSCI EAFE index. The MSCI EAFE index represents the market capitalization values of the main European, Australian and Far Eastern stock markets. These MSCI stock indexes do not contain dividends and the impact of dividend reinvestment returns to investors is not considered. This implies that the empirical specification and results of portfolio performance using these data will have a downward bias. This, however, is unlikely to materially affect the results since the difference between the price and the total returns version of the MSCI indexes is minimal and of no statistical significance.[1]

[1] See Appendix 3.1 for the statistical results of the F-test.

Table 3.1(A): Commodity Trading Advisor (CTAs) investment styles and descriptions

Investment Style	Descriptions
Currency CTAs[1]	Trade futures, forwards and options on currencies. Investors choose a particular CTA with an investment strategy that suits their risk preferences and have their funds managed by that CTA on an individual basis. Investments with CTAs are typically available only to investors with substantial net worth
Financial CTAs[1]	Trade futures, forwards, and options on fixed-income instruments
Diversified CTAs[1]	Trade futures, forwards, and options on all types of commodities and financial instruments
Discretionary CTAs[2]	The Discretionary CTA makes trading decisions with the use of human inputs and emotions. This type of manager often uses personal experiences to make and execute trading decisions, but may also use some sort of computer system as well. The key in this case is that the advisor may or may not, with almost equal probability, follow the signals being generated by the 'system'.
Trend Following CTAs[3]	Major elements in their approaches generally included diversification over several markets. Though this might appear to be similar with the Diversified CTA, one major difference lies on the focus of the method of exploiting trends, such as using more complicated mathematical criteria for trend identification, adequate capitalizations, and strict money management rules. This trading style (i.e., trend following styles), known to be used during the period of 1972 to 1977, is still being utilized in the Managed Futures industry today, according to a report published by the Managed Futures association dated November 1999, especially the Trend Following CTA.
MAR Trading Advisor Index[4]	The MAR (Managed Account Report) Trading Advisor Qualified Universe Index is a dollar-weighted Managed Futures index which includes performance of current as well as retired trading advisors. The Index goes back historically to 1980. Its objective is to provide a valid and reliable indication of what rate of return the Managed Futures industry is providing to investors, i.e., what is happening to the average investor's dollar. In order to be included in the "qualified" universe, a trading advisor must meet one of two requirements: have at least $500,000 under management and 12 months of trading client assets; or act as a trading advisor in a public fund that is listed in MAR's funds Table.

[1] source: Edwards & Caglayan, (2001).
[2] sources: Epstein, C.B. (1992), pg 125.
[3] source: A report (1999) published by Managed Futures Association, see www.mfainfo.org.
[4] source: A report (1999) published by RXR Capital Asset Management.

Table 3.1(B): Commodity Trading Advisor (CTAs) investment styles and the type of futures contracts commonly traded.

Investment Style	*Main Types of futures contracts traded*[2] [3]
Currency CTA	Trade mainly currencies futures. Most widely traded are, the futures contracts on the Switzerland France, the Japan Yen, the Canada Dollar, British Pound, Australian Dollar and the Mexican Peso.
Financial CTAs	Trade mainly currency, interest rate and stock index futures. Currency futures include: the Switzerland France futures, Japan Yen futures, Canada Dollar, British Pound, Australian Dollar and the Mexican Peso. Interest Rate futures include: Treasury Bonds, Treasury Notes, Eurodollars and LIBOR. Stock index futures include: Nikkei 225, S&P 500, S&P MidCap 400, Russell 2000 and Nasdaq 100.
Diversified CTA	Apart from trading all the futures contracts that are also traded by the Financial CTAs, Diversified CTA also trade futures on other type of grains, industrial, meats and soft products. Grain products include: wheat, corn, oats and soybeans products. Industrial products include: Crude oil, heating oil, Gasoline and Lumber. Meats products include: Cattle, Feeder Cattle, Hogs and Pork Bellies. Soft products include: cocoa, cotton, coffee, sugar and orange juice.
Discretionary CTA	Discretionary CTA trade the same type of futures product as the Diversified CTA, but they make trading decisions with the use of human inputs and emotions. This type of manager often uses personal experiences to make and execute trading decisions, but may also use some sort of computer system as well. The key in this case is that the advisor may or may not, with almost equal probability, follow the signals being generated by the 'system'.
Trend Following CTA[4]	Like the Discretionary CTA, Trend Following CTA invest in futures contracts similar to that of the Diversified CTA. One major difference lies on the focus of the method of exploiting trends, such as using more complicated mathematical criteria for trend *identification, adequate capitalization*, and *strict money management* rules.

[2] Source: "Derivatives traded Exchange in a Professionally Managed Portfolio Derivatives traded Exchange" published by Chicago Mercantile Exchange, 1999.

[3] More details on the trading strategies using more complex futures contracts and futures contracts portfolios are only available from Managed Futures traders. This empirical research deals mainly with numerical data obtained form the data vendors concerned. Managed Futures traders were not contacted. Further details on the type of futures contracts could not be made available, which is to why the Managed Futures data cannot be described comprehensively sometimes.

[4] source: A report (1999) published in Managed Futures Association, see www.mfainfo.org.

3.2.1.2 Selection and Choice of Data

This section provides the rationale for the selection and the choice of data, with respect to the use of methodologies adopted for the various empirical chapters. As Section 3.1 indicated, the empirical analysis of this thesis relies upon a number of portfolio optimization techniques. In practice, due to portfolio diversification concerns, optimization and asset allocation decisions normally involve the use of a large number of assets. In principle, all the assets available to the fund managers should be considered and be committed in the allocation process. There are, however, no arguments on the "right" number of assets to be input into the optimization and asset allocation process.

Chapter 4, which investigates the performance of Managed Futures within a downside risk framework, uses two alternative asset allocation frameworks. The empirical analysis in this chapter makes reference to similar existing studies when considering the appropriate number of assets to be included in the allocation process. The determination of the number of assets and the allocation methodology adopted for this chapter have been adopted from the Nawrocki (1992) study. Nawrocki (1992) uses a total of ten assets for his underlying asset allocation model, whilst in Chapter 4, twelve assets are used in the asset allocation process, consisting of five Managed Futures indexes and seven MSCI stock indexes.

The data selected for Chapter 4 are also converted into UK£'s via the currency forward rate. This assumes that the underlying foreign exchange markets and individual country stock markets to be well-developed and relatively liquid. The MSCI stock indexes selected for analysis were, following Eun & Resnick (1988), those that reflected the most mature and well developed foreign exchange markets. This consideration is necessary because, as with the analysis in Chapter 4, those stock indexes used in Eun & Resnick (1988) are also converted into the assumed investor's home currency (i.e., US dollars) using the currency forward market.

All the Managed Futures data used in Chapter 4 are downloaded from www.marhege.com. We only select those Managed Futures data starting from 1990. This is to be consistent with the existing literature on the selection of respective length of time periods for analysis. Following Stevenson (2001), another paper employing a similar methodology, the analysis in Chapter 4 used a 5 year period as the out-of-sample testing period. As the time period for analysis has to end in 1998[5] for this chapter, it requires the time period to begin from 1990. This then enables 1994 to 1998, a total of 5 years, to be used as the out-of-sample period and with the remaining 1990 to 1993 period as the in-sample estimation period[6]. The empirical analysis for Chapter 4 therefore standardized 1990 as the year for the beginning period and 1998 as the year for the ending period.

The portfolio optimization methodology used in Chapter 5 presents empirical challenges for moderately large systems of indexes. The number of parameters to be estimated increases with the use of more indexes and that may become too large given the relatively low number of monthly observations that can be obtained using these indexes. Chapter 5 therefore uses a relatively smaller number of indexes than Chapter 4. This is to ensure that the subsequent empirical research is, on one hand, operationally feasible whilst, on the other hand, remains a good representation of the underlying assets that the index is

[5] See Section 3.2.2 for a discussion on the data and time periods utilized in the empirical chapter.
[6] See footnote 17 of Chapter 4 for further discussion on the selection of the length for the in-sample period.

attempting to capture. This means the selected indexes have to be "broad base". As this chapter tests the impact of the volatility of US stocks held within a typical asset portfolio, the MSCI US stock index is therefore one of the three indexes used in this chapter. The other two indexes selected are the MSCI EAFE index, which most developed markets indexes include, and the MAR index which represents Managed Futures, since it is the most comprehensive index on Managed Futures firms and hence the best regarded index to represent the whole industry in the US.

Chapter 6 adopts a simplified version of a potentially complex trading system methodology. The whole idea of Chapter 6 is to show how the adaptation of "Active Currency Management" within a portfolio that uses Managed Futures can help enhance portfolio returns in UK£.

This approach is rarely being adopted in the academic literature, and, to date, no study focusing on UK investors has done so. The application of the technique to UK investor returns constitutes an important element of the contribution of this chapter to the existing literature. Moreover, in addition to the adoption of a simplified version of the actual complex trading systems used by Managed Futures fund managers, optimization of both a currency portfolio and an equity portfolio becomes unnecessary because only the US-dollar is used in the empirical analysis of this chapter. Furthermore, portfolios that consist of Managed Futures indexes, MSCI US and MSCI EAFE stock indexes in this chapter are all equally weighted. Therefore, this chapter also follows a simple portfolio construction methodology and hence does not involve as many MSCI stock indexes as those in Chapter 4. To maintain consistency, the same MSCI EAFE and the MSCI US stock indexes used in Chapter 5 are discussed in Chapter 6. For the Managed Futures indexes, those used in Chapter 4 are then also being discussed in Chapter 6 for the same reason.

3.2.2 The Data and Time Periods utilized in the Empirical Chapters

Due to data limitations and the different empirical approaches adopted by each of the empirical chapters, the specific time periods covered in each chapter differs slightly. In Chapter 4, the analysis covers the period from the beginning of 1990 to the end of 1998. The first 4-year period (i.e., 1990 to 1993) is the in-sample (estimation) period and the subsequent 5-year period, from 1994 to 1998, is our out of sample (testing) period(s).

The sample period ends in 1998 because several of the MSCI stock indexes (e.g., Germany and France) used in Chapter 4 ceased to exist after the introduction of the Euro in January 1999. This change in currency denominations could add volatility to the return series upon currency conversion to UK£. Due to this consideration, the use of corresponding CTA indexes data in the chapter is restricted to the period 1990 to 1998, in order to be consistent with the MSCI stock indexes.

In Chapter 5, the Managed Account Research's "Trading Advisor Qualified Universe" (MAR) index is used to represent the Managed Futures asset class. This is because among all the Managed Futures indexes available to us, this is the index that gives the best possible Managed Futures performance because it tracks the largest number of US-based Managed Futures firms by comparison to other benchmarks. It, therefore, gives the most comprehensive representation of the growth and performance of the Managed Futures industry. The analysis in this chapter uses two portfolios. One of the portfolios requires a

Managed Futures index to form part of the portfolio that consists of the MSCI EAFE index. The other portfolio consists of the MSCI EAFE stock and the MSCI US stock indexes. The only two stock indexes used in this chapter will therefore be the MSCI EAFE and the MSCI US indexes.

The range of time periods examined starts in 1980 and ends in 2001. The years 2000 and 2001 are two of the most volatile in the history of financial markets, and the empirical research would like to address the role of Managed Futures within an equity portfolio during these years of high volatility.

In Chapter 6, the CTA indexes used are the same as those used in Chapter 4. The MSCI US and the MSCI EAFE stock indexes used in Chapter 5 are also used in this chapter. In Chapter 6, the period studied is from 1990 to the end of 2001. Similar to Chapter 5, the highly volatile years of 2000 and 2001 are included.

Only Chapter 5 makes use of the MAR index, whereas Chapters 4 and 6 use CTA indexes, e.g., the Currency CTA, the Finance CTA, the Discretionary CTA, etc, since these should provide more detailed information regarding the relative return patterns associated with these different types of CTA investment strategies or categories. Table 3.2 provides a summary of the data used for the research, including the type of data and the respective time periods used for each empirical chapter. A discussion of the time-series graph of the indexes used in the thesis now follows.

Table 3.2: Summary of data used for Empirical Chapter 4, 5 and 6

Empirical Chapter	Managed Futures/MSCI stock indexes	Time Periods	No. of observations (Frequency of data)	Original currency denomination	Currency conversion into UK£	Reasons for the time period involved
Chapter 4	MSCI stock indexes: MSCI Canada stock index, MSCI France index, MSCI Germany index, MSCI Japan index, MSCI Swiss index, MSCI US index and MSCI UK index Managed Futures indexes: Trend-following CTA, discretionary CTA, diversified CTA, currency CTA and financial CTA	1990 to 1998	108 (Monthly)	**MSCI stock indexes:** Local currency of the country in which the specific stock index belongs to **Managed Futures indexes** US Dollars	Forward rates	The sample period ends in 1998 because several of the MSCI stock indexes (e.g., Germany and France) ceased to exist after the introduction of the Euro in January 1999. This change in currency denominations could add volatility to the return series upon currency conversion to UK£. Due to this consideration, the use of corresponding CTA index data in the chapter is restricted to the period 1990 to 1998, in order to be consistent with the MSCI stock indexes.
Chapter 5	MSCI stock indexes: MSCI US and MSCI EAFE indexes Managed Futures indexes: The Managed Account Research's "Trading Advisor Qualified Universe" index or the MAR Index	1980 to 2001	264 (Monthly)	**Both MSCI stock and Managed Futures indexes** US Dollars	Spot rates	The time period from 1980 to 2001 consists of 20 years. The time periods ended in 2001 because 2001 is one of the most volatile periods in the financial history. We want to investigate if using Managed Futures within a UK portfolio during this period will help to produce a different type of portfolio performance.
Chapter 6	MSCI stock indexes: MSCI US and MSCI EAFE indexes Managed Futures indexes: Trend-following CTA, discretionary CTA, diversified CTA, currency CTA and financial CTA	1990 to 2001	144 (Monthly)	**Both MSCI stock and Managed Futures indexes** US Dollars	No currency Conversion (i.e., data denominated in US$)	The time period from 1990 to 2001 is used so as to show how using active currency management and Managed Futures can be effective, if they were to be used within a UK equity portfolio, particularly during the volatile time period in 2000 and 2001.

3.2.3 Discussion of The Index Values and Returns Data for The Empirical Chapters

The primary source of the data reports is in local currency. All the CTA indexes from www.marhedge.com are in US$, while the MSCI stock indexes data downloaded from Data-stream are in their respective local currencies. Table 3.2 shows that the data is used in local currency only in Chapter 6. The data is converted into UK£ by the forward rates for use in the analysis of Chapter 4, and by the spot rates for use in the analysis of Chapter 5.

This section presents a discussion of the information underlying the data[7], both in the format of local currencies and in the format of converted data. Sub-sections 3.2.3.1 discusses index values (original local currency) and sub-section 3.2.3.2 discusses index returns (original local currency). The discussion of index returns will also be accompanied with the basic descriptive statistics of the return series. Sub-section 3.2.3.3 discusses the statistics of the return series in UK£ that are converted from various currencies.

3.2.3.1 Discussion of the Index Values (original local currency)

In this section, the time series features of index values denominated in local currency are discussed. The discussion will follow the sequence of chapters in which the data is used for empirical analysis. Therefore, Figure 3.1[8] is a time series plot, in local currency of MSCI stock indexes (Figure 3.1(A)) and CTA indexes (Figure 3.1(B)) from

[7] Here, the information underlying the data is restricted to a summary of standard descriptive statistics. Other information underlying the data that relate to the time series properties, such as autocorrelations will not be covered here. Chapter 5 considers the time series aspects of empirical analysis, and relevant time series properties, suited to the requirement of the empirical methods used in Chapter 5.
[8] Figure 3.1 to 3.6 are plots of either the index or the index returns and are all listed in sequence at the end of this chapter.

1990 to 1998. This data is used in Chapter 4, but is then converted into UK£ using forward exchange rates before being used further in this chapter. Figure 3.2 is a time series plot, in local currency of the MAR index, MSCI EAFE index and the MSCI US index from 1980 to 2001. This data is used in Chapter 5, but is then converted into UK£ using spot exchange rates before being used further in this chapter. Figure 3.3 is a time series plot, in local currency, of the various CTA indexes, the MSCI US index and MSCI EAFE index from 1990 to 2001. These data are used in Chapter 6 in the original local currency format.

Figure 3.1(A) shows that the patterns of the movements of the stock indexes (apart from the MSCI Japan stock index) are quite similar. They, however, vary in the degree of fluctuation. Some different degrees of fluctuation are observed before and after 1993. For the period between 1990 and 1993, all these stock indexes generally increase. For example, the MSCI US index increases gradually from slightly over 500 points in 1990 to 700 or 800 points by the end of 1993, while the MSCI Canada stock index increases from around 800 points to 1000 points, during the same period.

Some other stock indexes, such as the MSCI Germany stock index, increases from just over 400 points to around 500 points during the same period, while the France stock index increases from around 1000 points to 1300 points during the same period. Between 1994 and 1995, most of the MSCI stock indexes (except the MSCI Japan stock index) decrease slightly and then increase again towards the end of 1995. The MSCI US and MSCI Canada stock indexes, however, increase during the same period.

During the period from 1995 to the middle of 1997, upward trend movements are observed in most of the indexes (except for the MSCI Japan stock index). These indexes then fall slightly after the middle of 1997 before rising again as 1998 begins. The indexes then continue to rise until the middle of 1998, fall again roughly in the third quarter of 1998 before rising again towards the end of 1998.

Different from the movements of most other stock indexes, the MSCI Japan stock index falls from more than 2000 points beginning of 1990 to about 1000 points during the second half of 1992. It then stays around the same level, fluctuating within a narrow range before reaching about 1000 points during the second half of 1998. Stagnation and bubbles troubled the Japanese economy throughout the whole of 1990s and the movement of the stock market appears to reflect that.

Figure 3.1(B) shows that, throughout the years 1990 to 1998, all graphs of CTA indexes exhibit upward trends. However, compared with the various MSCI stock indexes in Table 3.1(A), the CTA indexes clearly exhibit greater differences in pattern, across each other, throughout 1990 to 1998. The Currency CTA, for example, has a different pattern from the rest of the CTA indexes. It reaches a small peak around the middle of 1993 before it declines to a temporary low around the beginning of 1995. It then increases towards 1998 and reaches about 290 points at around the third quarter of 1998. Discretionary CTA has the flattest pattern and trend movement compared to all other CTA discussed in this figure. The index values of Trend Following CTA fluctuate more frequently throughout the same time periods. It peaks in numerous occasions and declines quite quickly. For example, it reaches a peak point of around 600 in the middle of 1993 and then declines to a low level of slightly more than 500 points at the beginning of 1994.

Figure 3.2 shows the time-series plots of the MSCI EAFE index, the MSCI US index and the MAR index from 1980 to 2001. The MSCI EAFE and the MSCI US indexes have a similar pattern from September 1998. However, prior to this year, both indexes move very differently. The MSCI US index moves rather gradually, while the MSCI EAFE index appears to fluctuate more frequently, particularly between the periods from the middle of 1987 to the middle of 1997. Both indexes, however, show a down trend towards 2001. The MSCI EAFE index shows a downward trend from the beginning of 2000, but the MSCI US index, shows a similar trend from the middle of 2000. The MAR index shows an upward trend during the period 1980 to 2001, but falls to a low of 1500 points around the third quarter of 2000. However, unlike the MSCI US and MSCI EAFE indexes, it exhibits an upward trend towards the end of 2001.

Figure 3.3 shows the time-series plots of the various CTA indexes, the MSCI EAFE index and the MSCI US index, from 1990 to 2001. As the movements of the other CTA indexes, from 1990 to 1998, have been discussed in Figure 3.1(B), the following discussion will therefore focus on the years 1999 to 2001. Figure 3.2 already exhibits the graphs of the MSCI EAFE and US stock indexes from 1980 to 2001 and since this covers the period from 1990 to 2001, they will therefore not be repeated here[9].

Figure 3.3 shows that all the CTA indexes experience upward trends from 1999 to 2001, but in-between these two periods, Finance CTA, Trend Following CTA and Diversified CTA seem to experience frequent episodes of high volatility. The Currency CTA and Discretionary CTA indexes tend to experience these to a lesser extent. For the

[9] The graphs plotting the trends, however, are still shown for EAFE and US Stock indexes in Figure 3.2, so that it is clear which set of data are being used for analysis (i.e., in Chapter 6) from 1990 to 2001.

Finance CTA and Trend Following CTA indexes, there appears to be a downward trend starting from the second half of 1999 cutting in the last quarter of 2000. This is then followed by an upward trend into 2001. The Diversified CTA index also exhibits a downward trend between the second half of 1999 and the fourth quarter of 2000. However, relative to the Finance CTA and the Trend Following CTA indexes, episodes of high volatility are less frequent between these two dates. An upward trend pattern is then observed for these three CTA indexes from the fourth quarter of 2000.

In summary, the discussion of the movements of both the MSCI stock indexes and Managed Futures indexes show that the various Managed Futures indexes exhibit greater differences in pattern when compared with the MSCI stock indexes. This is to be expected due to the growing integration of the international stock markets[10]. The movements of the various Managed Futures indexes appear to exhibit greater individual differences since return outcomes can be expected to reflect differences in the strategies adopted and the type of financial futures contracts being traded. The observation of the low correlations between index movements of Managed Futures and MSCI stock indexes is of significant importance to the empirical analysis of this thesis. From a portfolio diversification perspective, it will therefore be interesting to investigate the effect upon portfolio performance arising from having a portfolio of MSCI stock indexes (of similar movement patterns) combined with Managed Futures indexes (of different movement patterns). Indeed, using 3 different portfolio allocation mechanisms, different aspects of this issue are addressed in each of the following empirical Chapters 4, 5 and 6.

[10] The extant literature provides convincing evidence that financial markets do influence each other. For example, Kock and Kock (1991) provide evidence on the evolution of contemporaneous and lead/lag relationships among eight national stock markets. They suggest that regional interdependencies have grown over time.

3.2.3.2 Discussion of Index Returns (original local currency)

Table 3.3 shows the descriptive statistics summary of index returns (original local currency), listed separately for the periods 1990 to 1998 (Table 3.3(A)), 1980 to 2001 (Table 3.3(B)) and 1990 to 2001 (Table 3.3(C)). Figure 3.4 contains time-series plots of the returns of the various MSCI stock indexes (Figure 3.4(A)) and Managed Futures indexes (Figure 3.4(B)) during the time period 1990 to 1998. This corresponds to the indexes discussed in Table 3.3(A).

From Figure 3.4(A), it can be seen that the Japanese stock index experiences the greatest fluctuations. Most of them are near 10%, apart from 1990, 1994 and 1998, in which there are times when it falls more than 10%. As seen from the descriptive statistics of Table 3.3(A), the Japanese stock index also has the highest standard deviation of 6.5%. The minimum return of -19.6% is also the lowest across all other stock indexes.

Among European and other US indexes, the US stock index has the lowest standard deviation of 3.9%. European indexes, however, exhibit standard deviations between 4.1% and 5.8%. These European and the US stock indexes also exhibit significant negative skewness (apart from the France and the UK stock indexes).

Figure 3.4(A) also shows that the returns of the various European stock indexes and the US stock index can be as low as 20%. This appears to be the case for the Swiss, Canadian, Japanese and German stock markets. The Canada stock and the Switzerland stock indexes experience a 20% fall in the second half of 1998, while the Germany and the

Table 3.3: Descriptive statistics summary for the Returns of the index values (original local currency)(Discussed with section 3.2.3.2)

A) Descriptive Statistics for the returns of the MSCI stock/Managed futures indexes from 1990 to 1998

MSCI Stock Indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera (JB)
MSCI Canada index	0.76%	11.62%	-18.85%	4.14%	-0.82	***-3.48	3.783	***68.99
MSCI Germany Index	1.18%	15.70%	-18.19%	5.77%	-0.78	***-3.3	1.682	***21.68
MSCI France Index	1.05%	13.09%	-13.65%	5.60%	-0.32	-1.36	-0.194	2.11
MSCI Japan Index	-0.49%	16.78%	-19.60%	6.47%	0.07	0.28	0.635	1.45
MSCI Switzerland Index	1.53%	14.02%	-18.16%	5.41%	-0.77	***-3.27	1.713	***21.94
MSCI UK Index	1.23%	11.98%	-9.38%	4.27%	-0.12	-0.5	0.072	0.25
MSCI US Index	1.41%	11.34%	-13.94%	3.86%	-0.64	***-2.71	1.881	***20.94
Currency CTA	1.06%	16.36%	-8.17%	4.17%	1.22	***5.16	6.972	***54.71
Finance CTA	1.20%	20.17%	-8.56%	4.07%	1.17	***4.96	6.589	***79.9
Diversified CTA	0.92%	12.69%	-7.53%	3.67%	0.46	**1.93	3.590	4.23
Discretionary CTA	1.10%	8.67%	-4.57%	2.18%	0.56	*2.39	4.179	*8.62
Trend Following CTA	1.12%	22.03%	-10.38%	5.01%	0.92	***3.91	4.876	***30.44

B) Descriptive statistics for the returns of the MSCI stock/Managed Futures indexes from 1980 to 2001

MSCI StockManaged futures indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera (JB)
MAR Index	1.20%	24.29%	-9.96%	4.88%	1.15	***4.87	6.095	***163.34
MSCI EAFE Index	0.84%	15.40%	-14.11%	5.02%	-0.17	-0.73	3.293	2.23
MSCI US Index	0.96%	13.05%	-21.67%	4.42%	-0.63	***-2.67	5.482	***85.2

C) Descriptive statistics for the returns of the MSCI stock/Managed Futures indexes from 1990 to 2001

Managed Futures indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera (JB)
Currency CTA	0.87%	16.36%	-8.17%	3.70%	1.44	***6.09	6.972	***144.11
Finance CTA	0.96%	20.17%	-8.56%	3.88%	1.11	***4.71	6.589	***106.85
Diversified CTA	0.83%	12.69%	-7.53%	3.42%	0.48	*2.03	3.590	*7.61
Discretionary CTA	1.01%	8.67%	-4.57%	2.02%	0.65	*2.76	4.179	***18.49
Trend Following CTA	0.95%	22.03%	-10.38%	4.78%	0.78	***3.3	4.876	***35.65
MSCI US Index	0.90%	10.36%	-14.34%	4.19%	-0.46	*-1.97	3.554	*6.99
MSCI EAFE Index	0.19%	15.40%	-14.08%	4.91%	-0.09	-0.39	3.376	1.05

Notes:1) (*) indicates 5% level significance (critical value for z-test is 1.96; critical value for chi square is 5.991), (**) indicates 10% level signifcance (critical value for z-test is 1.65 critical value for chi square is 4.61) and (***) 1% level significance (critical value for z-test is 2.58; critical value for chi square is 9.21). 2)The return of the index values, in original local currency, are not used as data input for empirical analysis. This information is provided here as part of our general discussion on the use of our dataset for research. Table 3.4 provides details of the actual data being used as input for empirical studies.The data used in table 3.4 are in UK£ and not in local currency. 3) The Skewness Z-statistics is estimated as z = S/(6/N)0.5 while the Jarque-Bera Statistics tests for skewness by taking into account kurtosis (the value left to the column of JB statistics as above). It is estimated as JB = N[s2/6 + (k-3)2/24], where S denotes the value of skewness and k denotes the value of kurtosis, N denotes the number of data used for the test. The JB test follows a chi square distribution with 2 degree of freedom.

Japanese stock indexes experience similar level of reductions around the second half of 1990. The German stock index experiences yet another fall to about 16% in the second half of 1998 and so does the Japanese stock index, but the latter only experiences a falls of slightly less than 15%.

As for the largest monthly fall across the remaining stock indexes, the France stock index experiences an estimated 14% fall in the second half of 1990, and the US stock market experiences a similar fall in the second half of 1998. Figure 3.4(A) shows that for the UK stock market, the maximum fall is only about 10%, occurring in the second half of 1998. This appears to correspond to the minimum return of -9.38% as shown in Table 3.3(A).

Figure 3.4(B) shows time-series plots of the returns of the CTA indexes. These correspond to the descriptive statistics presented in Table 3.3(A). They cover the period from 1990 to 1998. From these figures, it is observed that the movements of the various CTA returns follow the same pattern. Returns of the Currency CTA fluctuate relatively more frequently between 1990 and 1994, but the graph flattens out after that. The Trend Following CTA has the most frequent episodes of high volatility throughout the period - the monthly fall in the index return is as high as 12%. The Discretionary CTA appears to have the most stable return series - the largest monthly fall is only slightly less than 5% at the end of 1990. In fact, the minimum return of -4.57% for the Discretionary CTA is the highest among all other CTAs listed in Table 3.3(A). The Finance CTA and the Diversified CTA, however, fluctuate relatively less in comparison to the Trend Following CTA. Their standard deviations are 4.07% (Finance CTA) and 3.67% (Diversified CTA). As for the Trend Following CTA, the standard deviation of about 5% is the highest amongst all the various CTA indexes. These are all shown in Table 3.3(A). All CTAs, apart from the Diversified CTA, exhibit significant positive skewness of at least 5%. This shows that the probability distribution of the CTA index returns tend to be higher than the mean values.

Figure 3.5 shows time-series plots of returns of the MSCI EAFE index, the MSCI US index and the MAR index. These plots cover the period from 1980 to 2001, corresponding to the descriptive statistics in Table 3.3(B). The graphs show that the MAR index returns exhibit more frequent episodes of high volatility during the period from 1980 to 1994 than during the period from 1994 to 2001. As the MAR index tracks the performance of the entire Managed Futures industry, this observation simply shows that increased competition (due to larger numbers of entrants into the industry) in the Managed Futures industry after 1994 has tended to drive returns downward. It is observed that monthly returns greater than 10% no longer occur after 1994. On the other hand, The MSCI EAFE index appears to fluctuate more frequently compared to the MSCI US index.

Comparing the three indexes, the descriptive statistics in Table 3.3(B) show that the MAR index and the US index both have similar standard deviation of 4.4% and 4.8%, respectively. However, the MAR index has a minimum return of around -10%, while the US index has a minimum return of -21.7%. The MAR index also exhibits a positive skewness of 1.14, while the MSCI EAFE and the MSCI US indexes are negatively skewed. However, between the two indexes, the skewness of only the MSCI US index is statistically significant (at 1%).

Figure 3.6 presents return graphs of the various CTA indexes, the MSCI EAFE index and the MSCI US index returns, from 1990 to 2001. Movements of the returns of the CTA indexes other than the MSCI EAFE and the MSCI US have already being presented and discussed for the period from 1990 to 1998, in Figure 3.4(B). The subsequent discussion of these CTA index returns will, therefore, focus on the period from 1999 to 2001. Table 3.3(C) provides summary statistics, corresponding to the return patterns of the CTA and the MSCI indexes shown in Figure 3.6.

Figure 3.6 shows that between 1999 and 2001, Currency CTA returns appear to fluctuate relatively less often, while the Discretionary CTA returns seem to fluctuate more often, within the positive range of returns than within the negative range. Comparing Diversified CTA, Trend Following CTA and the Finance CTA, the Diversified CTA seems to fluctuate within a smaller range with negative returns of only about -4%,, while the Finance CTA returns fluctuate within a range with negative returns of less than -5% between 1999 and 2001, but fluctuates towards -10% by the end of 2001. The Trend Following CTA fluctuates quite widely on the negative returns range during the last quarter of 1999, approaching -8%, and again in the first quarter of 2001. It then falls to more than -10% by the end of 2001.

The return fluctuations observed between 1999 and 2001, however, do not really contribute much change to the descriptive statistics observations between 1990 and 2001. It is observed from Table 3.3(C) that taking on the additional years from 1999 to 2001 (as compared to Table 3.3(A) which reports summary statistics for the same CTA indexes but for the period from 1990 to 1998), not only do they not change the maximum and the minimum returns, they also reduce the standard deviations. Table 3.3(C) shows that the standard deviation decreases when observations of the 1999 to 2001 are included. Currency CTA standard deviation reduces by 0.47 to 3.7%, which is the largest reduction, while that of the Discretionary CTA reduces by only 0.16 to 2.02%, which is the smallest reduction. However, the Trend Following CTA shares with other CTA indexes the largest standard deviation of 4.28%.

The graphs and the discussion of return fluctuations between 1990 and 2001 of the MSCI EAFE and US stock indexes have already been presented when Figure 3.5 was discussed. This is because Figure 3.5 presents graphs of returns of the period from 1980 to 2001 and that naturally includes the years from 1990 to 2001. As far as the descriptive statistics are concerned, removing ten years of observations (i.e., calculating the descriptive statistics from 1990 to 2001, instead of 1980 to 2001) only reduces the standard deviations slightly by 0.11 to 4.19% (MSCI EAFE index) and by 0.23 to 4.91% (MSCI US index), as shown in Table 3.3(C). However, Table 3.3(C) shows that the maximum and minimum returns of the MSCI EAFE and the MSCI US indexes are different throughout 1990 to 2001 than those reported in Table 3.3(B) when the years 1980 to 1989 are included. For the MSCI EAFE stock index, the maximum return remains the same, while the minimum return increases slightly by 0.03 to -14.08%. For the MSCI US stock index, the maximum return reduces by 2.69% to 10.36%, while the minimum return increases by 7.33% to -14.34%.

3.2.3.3 Discussion of Index Returns (in UK£, converted using spot rates or forward Contracts) used in the empirical Chapter 4, 5 and 6

This section discusses the index return data that are used in the empirical analysis. This set of data is the transformed data that are converted from their respective local currencies into UK£, using either the spot rate (Chapter 5) or the forward contract (Chapter 4). The analysis of Chapter 6 uses the data in local currency format.

Graphs[11] of these return series have very similar patterns to the returns series in original local currency (discussed in section 3.2.3.2 in Figure 4 to Figure 6)). This is not surprising because the distributions of the two return series are found not to be significantly different, as discussed in Appendix 3.2. However, as the transformed data are still numerically different from the original data, because of currency conversion, the discussion of the descriptive statistics will therefore be carried out. Table 3.4 shows the descriptive statistics of index returns (in UK£) used in Chapter 4 (Table 3.4(A)), Chapter 5 ((Table 3.4(B)) and Chapter 6 ((Table 3.4(C)). A comparison with the descriptive statistics reported in Table 3.3 (index returns denominated in local currency) and Table 3.4 (index returns denominated in UK£) should now follow.

Comparing the descriptive statistics of the data used in Chapter 4, in Table 3.3(A) and Table 3.4(A), shows that the differences arising from currency conversion are not very large. In fact, nearly all the descriptive statistics increase after returns are converted into UK£.

[11] These drawn up graphs are not shown in the chapter since they are not very dissimilar from those discussed in section 3.2.3.2, but they are available upon request.

Table 3.4: Descriptive Statistics summary for the Returns of the index values (in UK pounds converted from either the spot rates or forward rates) that are used as data inputs for empirical studies for chapter 4, 5 and 6 (Discussed with section 3.2.3.3)

A) Descriptive statistics for the returns of the MSCI stock/Managed Futures indexes, from 1990 to 1998, used in chapter 4

MSCI Stock Indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera
MSCI Canada index	0.90%	11.83%	-18.73%	4.15%	-0.81	***-3.45	3.765	***68.21
MSCI Germany Index	1.36%	16.06%	-17.75%	5.79%	-0.71	***-3.03	1.559	***18.44
MSCI France Index	1.16%	13.48%	-13.31%	5.61%	-0.28	-1.19	-0.255	1.82
MSCI Japan Index	-0.04%	17,33%	-19.11%	6.48%	0.07	0.3	0.628	1.42
MSCI Switzerland Index	1.83%	14.58%	-17.73%	5.43%	-0.71	***-3.03	1.585	***18.74
MSCI UK Index	1.23%	11.98%	-9.38%	4.27%	-0.12	-0.5	0.072	0.25
MSCI US Index	1.66%	11.97%	-13.79%	3.85%	-0.62	***-2.62	1.996	***22.24
Currency CTA	1.31%	16.93%	-7.65%	4.24%	1.28	***5.44	2.749	***59.31
Finance CTA	1.46%	20.76%	-8.04%	4.10%	1.22	***5.16	3.882	***86.57
Diversified CTA	1.17%	13.24%	-7.01%	3.68%	0.49	*2.07	0.467	**4.99
Discretionary CTA	1.35%	9.32%	-4.02%	2.23%	0.67	***2.85	0.990	***11.67
Trend Following CTA	1.37%	22.63%	-9.87%	5.04%	0.97	***4.13	2.091	***33.97

B) Descriptive statistics for the returns of the MSCI stock/Managed Futures indexes, from 1980 to 2001, used in chapter 5

MSCI Stock/Managed futures indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera
MAR Index	1.42%	26.44%	-10.60%	5.45%	1.35	***5.73	4.584	***208.1
MSCI EAFE Index	0.87%	13.16%	-19.97%	4.82%	-0.70	***-2.95	4.540	***47.33
MSCI US Index	1.18%	13.29%	-22.28%	5.04%	-0.61	***-2.58	6.409	***43.92

C) Descriptive statistics for the returns of the MSCI stock/Manged Futures indexes, from 1990 to 2001, used in chapter 6

Managed Futures indexes	Mean	Max	Min	Std. Dev.	Skew	z-test	Kurtosis	Jarque-Bera
Currency CTA	0.87%	16.36%	-8.17%	3.70%	1.44	***6.09	6.972	***144.09
Finance CTA	0.96%	20.17%	-8.56%	3.88%	1.11	***4.71	6.589	***106.86
Diversified CTA	0.83%	12.69%	-7.53%	3.42%	0.48	*2.03	3.590	*7.61
Discretionary CTA	1.01%	8.67%	-4.57%	2.02%	0.65	*2.76	4.179	***18.52
Trend Following CTA	0.95%	22.03%	-10.38%	4.78%	0.78	***3.3	4.876	***35.64
MSCI US Index	0.90%	10.36%	-14.34%	4.19%	-0.46	*-1.97	3.554	*6.99
MSCI EAFE Index	0.19%	15.40%	-14.08%	4.91%	-0.09	-0.39	3.376	1.05

Notes:1) (*) indicates 5% level significance (critical value for z-test is 1.96; critical value for chi square is 5.991), (**) indicates 10% level signifcance (critical value for z-test is 1.65; critical value for chi square is 4.61) and (***) at 1% level significance (critical value for z-test is 2.58; critical value for chi square is 9.21). 2) Table 3.4 (C) is the same as 3.3(C) because this Chapter used local currency returns data for analysis. 3) The Skewness Z-statistics is estimated as $z = S/(6/N)^{0.5}$ while the Jarque-Bera Statistics tests for skewness by taking into account kurtosis (the value left to the column of JB statistics as above).
It is estimated as $JB = N[s^2/6 + (k-3)^2/24]$, where S denotes the value of skewness and k denotes the value of kurtosis, N denotes the number of data used for the test.The JB test follows a chi square distribution with 2 degree of freedom.

For the MSCI US index, the maximum return increases by 63 basis points ("bp") to 11.97%, the highest increase across the various stock indexes. The Discretionary CTA index return increases by 65 bp to 9.32%. However, the Trend-Following CTA remains the CTA with the highest maximum return of 22.63%. As for the minimum return, the MSCI Japan stock index increases by 49bp to -19.11%, while that of the Discretionary CTA again increases the most by 55 bp to -4.02%, among the various CTA indexes. The Discretionary CTA also has the highest minimum return across all MSCI stock indexes and Managed Futures indexes.

It is observed that, apart from MSCI US index where standard deviation decreases by 1 bp to 3.85%, the standard deviations of all other MSCI stock indexes and Managed Futures indexes has increased. The standard deviation of the Currency CTA increases by 7 bp to 4.24%, while those of the MSCI Canada stock index, France stock index, Japan stock index and Diversified CTA only increase by 1 bp to 4.15%, 5.61% and 3.68% respectively. Even though the standard deviation of the Discretionary CTA increases by 5 bp to 2.23%, this index remains to be the one with the least standard deviation when compared with other stock or futures indexes.

It is also observed that the values of skewness increase for most MSCI stock indexes and Managed Futures indexes. Similar to Table 3.3(A), Table 3.4(A) shows that, apart from the MSCI Canada, MSCI Germany, MSCI Switzerland, MSCI UK and MSCI US stock indexes, which are negatively skewed, all other stock or Managed Futures indexes remain positively skewed. Among them, the Discretionary CTA is observed to have the highest increase of 11 bp in its skewness value to 0.6711.

Comparing Table 3.4(B) with Table 3.3(B), in which the data used for Chapter 5 are described, it is observed that there are some relatively large changes in the values of the descriptive statistics after currency conversion. However, among them, the MSCI US stock index shows the least change in the values of its descriptive statistics, while the MSCI EAFE stock index shows the greatest change.

While the mean value of the MSCI EAFE index returns increase by only 2 bp, its maximum and minimum return, however, decrease by 2.25% and 5.86% to 13.16% and -19.97%, respectively. This also reduces the standard deviations of the MSCI EAFE stock index returns by 20 bp to 4.82%. The standard deviation of the MSCI EAFE stock index in its local currency format was the highest at 5.02%, as shown in Table 3.3(B). However, it decreases to 4.82% and became the lowest of all the 3 indexes used for Chapter 5. It is also observed from Table 3.4(B) that the skewness of the MSCI EAFE Stock index is significantly negative at -0.7. It is interesting to note that, the return of the EAFE index denominated in local currency is not significantly negatively skewed.

It is also observed from Tables 3.3(B) and 3.4(B) that even though the mean values of the MAR index and the MSCI US index increase by about 22 bp and 23 bp, the MAR Index, however, has a higher increase of maximum return of 2% to 26.676%, while that of the MSCI US index only increases by 24 bp to 13.29%. Their minimum returns decrease by 61 bp (MSCI US index) and 64 bp (MAR index) to around -10.6% and -22.3%, respectively. The returns of the MAR index and MSCI US index continue to be significantly positively skewed and negatively skewed respectively after currency conversion. The skewness of returns increase for both the MAR index and the MSCI US index by 20 bp and 2 bp to 1.35 and -0.6089, respectively.

Table 3.4(C) shows the descriptive statistics of the data used in Chapter 6. The data used for empirical analysis in this chapter are all in local currency format and these have already been discussed in sub-section 3.2.3.2 and described in Table 3.3(C).

In summary, the discussion of the descriptive statistics of the data in Section 3.2.3.2 and 3.2.3.3 reveal that Managed Futures indexes are mostly significantly positively skewed, while the MSCI Stock indexes are mostly significantly negatively skewed. Furthermore, Managed Futures indexes also tend to have lower minimum returns of not more than -10% in most cases. This is an important characteristic of returns, especially concerning the portfolio allocation mechanisms that take into account skewness, and especially so, when both MSCI stock indexes and Managed Futures indexes are considered within the same portfolio. This will be the empirical studies for Chapter 4. On the other hand, it is also observed from Table 3.4(B) that all the indexes are significantly non-normal at 1% level, judging from the Jarque-Bera statistics. This is also an important characteristic, especially concerning the portfolio allocation mechanisms that consider conditional volatility. This will be an issue to be addressed in the empirical studies in Chapter 5.

3.2.4 The Treatment of Exchange Rate Conversion and Its Implications

After discussing the data in the previous sections, the exchange rate conversion methods will now be discussed. Section 3.2.3.3 mentioned that forward rates are used to convert local currency into UK£ for Chapter 4, while spot rates are used for Chapter 5. The main aim in this section is to explain the choice of using either spot rates or forward rates for these empirical chapters. Unlike the US-based literature reviewed in Chapter 2, currency conversion is an important issue for our research into the benefits of using offshore Managed Futures products within a UK portfolio context. As a result, the issues surrounding currency conversions cannot be ignored. Indeed, the method by which returns are converted from US$ to UK£ may have a material effect on returns to UK-based investors.

The issue of currency conversion has been addressed by Eun & Resnick (1988). These authors show that using forward contracts in the currency conversion might help to reduce overall portfolio return variability. This, however, need not necessarily be the case at all times. They demonstrate that portfolio return variance also depends on the variability between spot rates and the returns in local currency of the underlying portfolio's assets.

Table 3.5 adopts the illustration of Eun & Resnick (1988). In this table, the 100%-hedged asset's returns are denoted by $R_{i£}^{H}$. The variance of the 100%-hedged return (i.e., $Var(R_{i£}^{H})$)) is approximately equal to the variance of the underlying asset's local currency returns (i.e, $Var(R_i)$)). Hence, $Var(R_{i£}^{H}) \approx Var(R_i)$. This is because if the forward contract is used, the exchange rate conversion would then be confirmed in advance and hence the asset is safeguarded against any foreign assets' exposure. Therefore, the only source of variability comes from the underlying asset's local currency return. However, for un-hedged returns, i.e., 0%-hedged returns, the source of the variability of comes from the underlying asset's local currency returns and the spot exchange rate returns separately. Furthermore, the covariance of these two underlying returns is also another source of variability for the un-hedged returns. Eun & Resnick (1988) consider variance of un-hedged returns [i.e., $Var(R_{i£}^{e})$] to be made up of the variance of the underlying asset, $Var(R_i)$, the variance of the spot exchange rate return, $Var(e_i)$ and the covariance of these

Table 3.5: Summary of the decomposition of the volatility of stock market data returns in UK£

A) Variance decomposition analysis for data used in chapter 4

*MSCI Stock/Managed Futures indexes **	$Var(R^H_{i£})$ ***	$Var(e_i)$	$Cov(R,e_i)$	$Var(R^e_{i£})$
MSCI UK	1.82			1.82
MSCI USA	1.48	1	0.04	2.56
MSCI Japan	4.2	1.75	-0.14	5.62
*MSCI Germany***	3.35	0.55	-0.36	3.12
*MSCI France***	3.14	0.59	-0.31	3.07
*MSCI Switzerland***	2.95	0.73	-0.38	2.87
MSCI Canada	1.72	1.08	0.2	3.18
Trend Following CTA	2.54	1	-0.19	3.1
Discretion CTA	0.5	1	0	1.47
Diversified CTA	1.35	1	-0.11	2.11
Currency CTA	1.79	1	-0.01	2.7
Finance CTA	1.68	1	-0.23	2.18

B) Variance decomposition analysis for data used in chapter 5

*MSCI Stock/Managed futures indexes **	$Var(R^H_{i£})$ ***	$Var(e_i)$	$Cov(R,e_i)$	$Var(R^e_{i£})$
MSCI US	3	0.68	-0.04	3.6
*MSCI EAFE***	3.20	0.68	-0.45	2.98
MAR	3.49	0.68	-0.07	4.02

Note: (*) indicates that all values to be multiplied by 10^{-3}. (**) indicates Stock market returns where $Var(R^H_{i£}) > Var(R^e_{i£})$, this means the variance of hedged returns could be higher than un-hedged returns. (***) is denoted as the variance of hedged strategy. This is approximately equal to the variance of the asset's underlying local currency returns, which Eun & Resnick (1988) denotes as $\text{Var}(R_i)$. Eun & Resnick (1988) denoted variance of 0% un-hedged stock returns as $Var(R^e_{i£})$ and approximately equals to $Var(R_i)$ (i.e., variance of asset's underlying local currency returns) + $Var(e_i)$ (i.e., variance of the spot currency returns) + $2Cov(R_i,e_i)$ (i.e., covariance of the underlying asset's local currency returns and the spot currency returns).

underlying returns, $Cov(R_i, e_i)$. Therefore, the overall 0%-hedged returns can be estimated (approximately) as $Var(R_{it}^{e}) \approx Var(R_i) + Var(e_i) + 2Cov(R_i, e_i)$. Eun & Resnick (1988) explain that, though using the forward contract as a hedging tool can reduce the variability of returns considerably (since the exchange rate is pre-determined in the contract already), sometimes the resulting variability is higher than obtained from simply using spot rates. This is especially true when the covariance between the spot exchange rate returns and stock (in local currency) returns is low.

Table 3.5 shows the decomposition of the variance of the various market indexes used in Chapter 4 (Table 3.5(A)) and Chapter 5 (Table 3.5(B)). The currency conversion decisions for Chapter 6 are different. In Chapter 6, currency is considered as an asset class, and the issue is about whether or not differential potential profit opportunities are available from using alternative currency conversion methods. Contingent hedging mechanisms of alternative currency conversion methods are a popular form of "Active Currency Management". A fuller discussion of the relevant literature is undertaken in Chapter 6. The Active Currency Management strategies that are to be evaluated are claimed to be able to first identify currency trends and then to provide a signal to hedge (not hedge) when persistent depreciation (appreciation) of the foreign currency is expected.

Table 3.5(A) shows that, for the variance decomposition analysis of data used in Chapter 4, the variance of hedged returns (indicated by $Var(R_{i£}^{H})$ in the table) of MSCI stock and Managed Futures indexes is lower than that of un-hedged returns (indicated by $Var(R_{i£}^{e})$), except for the MSCI Germany, the MSCI France and the MSCI Switzerland stock indexes, in which the variability of their hedged returns is much higher than that of their un-hedged returns. Moreover, among these indexes, the variability of hedged returns of the MSCI Germany stock index is about 7.4% higher than that of its un-hedged returns. This is the largest variability of all the three MSCI stock indexes. Even so, it is noted that the majority of the stock indexes reported in Table 3.5(A) still reveal that the variability of their hedged returns ($Var(R_{i£}^{H})$) is lower than that of their un-hedged returns ($Var(R_{i£}^{e})$).

Chapter 4 therefore uses the forward contract for currency conversion[12] of the data. It is also noted that, Stevenson (2001) and Harlow (1991), who apply the same methodology as that used in Chapter 4, i.e., downside risk/Lower Partial Moment framework, also employ forward contracts for currency conversion when transforming their data into US$.

The analysis in Chapter 5 uses conditional volatility within an optimization framework. In this chapter, spot rates are used for currency conversions. Table 3.5(B) reports that currency conversion using spot rates, results in a higher variability of UK£ returns than when forward contracts are used. The table shows that the variance of un-

[12] Eun and Resnick (1988) also show that the cash flow, proceeds and transaction taken place during the hedging process that used the foreign exchange forward contract can be estimated with minimum underlying errors. Appendix 3.3 discusses and explains the details.

hedged returns, ($Var(R^e_{i£})$), of the Managed Futures indexes and, especially, of the MSCI US index, is 20% higher than that of hedged returns, ($Var(R^H_{i£})$).

However, the reverse seems to be the case for the MSCI EAFE index. Table 3.5(B) shows that the hedged return variability is much higher for this index – about 7.4% higher - than that of the variability for the un-hedged returns. Though this is the case, using spot rates for conversion appears more plausible for the type of empirical analysis used, which involves conditional volatility. Indeed, in Chapter 5, it is shown that the UK£ returns of the three market indexes, converted using spot exchange rates, reveal the presence of the GARCH[13] effects. This then allows for analysis involving volatility modeling issues that are needed for the empirical research in Chapter 5.

3.2.5 Limitations of the Data

The MSCI and Managed Futures indexes are all value weighted. One issue that concerns the Managed Futures industry is that CTAs who operate off-shore outside the United States, normally do not need to register with the US regulator, the Commodity Futures Trading Commission (CFTC). However, those who deal with selling Managed Futures products to US investors, must register with the CFTC and are obliged to adhere to a specific disclosure policy (see Fox-Andrew & Meaden (1995)).

[13] GARCH is the short form for "Generalised Autoregressive Conditional Heteroscedasticity". It is a technique used to estimate time-varying or conditional variance. Table 5.2 of Chapter 5 provides empirical evidence showing the presence of the GARCH effect using spot exchange to convert US Dollars into UK£.

One concern with regard to the data is due to the less comprehensive information disclosures and regulation requirement of the Managed Futures industry and that it is known to have survivorship and self-selection biases. These biases apply to all the Managed Futures data used in the thesis. It has to be noted that adjusting for survivorship and self-selection bias has not been possible due to difficulties in accessing the complete data base of CTA companies underlying the indexes. Nevertheless, the research into survivorship bias relating to the CTA data may provide some important insights into the likely extent that our final results might be affected by such biases, particularly the likely effect and the downward biases of the portfolio returns that are reported towards the end of each of the empirical Chapter 4, 5 and 6, judging from the figures provided by the survivorship bias findings on the CTA data that is presented in the following.

Fung & Hsieh (1997) examine surviving and defunct funds operated by CTAs from 1989 to 1995. They find that a commodity fund drops out of the database with a probability of 19% per year. The survivorship bias, i.e., the performance differences between the surviving portfolio and the observable portfolio, average about 3.4% per year. Fung & Hsieh (2000) update the results of Fung & Hsieh (1997) by adding two more years of data. They find that between 1989 and 1997, the observable portfolio returned an average 15.5% per year, while the surviving portfolio returned 19.1%. They conclude, therefore, that the survivorship bias in published commodity fund indexes is approximately 3.6% per year.

Nevertheless, there is no standard guideline on the "right use" of Managed Futures indexes to conduct investment (academic or professional) research. It all depends on the underlying aim and purpose in which the data are used. The main purpose for using indexes related data for the research in this thesis is due to our assumption that the UK investor only undertakes tactical asset allocation and therefore no security selections are involved in the process[14]. Similar use of the Managed Futures indexes, particular similar to the way being used in this thesis, can also be found in Schneeweis & Spurgin (1997). Their research, however, conduct relative studies on the tracking errors differences among Managed Futures benchmarks/indexes, which has a different purpose and is therefore entirely different from the research conducted in this thesis.

3.2.6 Software Packages Used for the Empirical Chapters

Most of the analyses in the Thesis involve optimization. For example, in Chapter 4, the Minimum Variance and the Minimum Lower Partial Moment optimizations are used, and in Chapter 5, the time-varying variances and covariance data are fed into the optimization process. For the optimization methods in these two chapters, Microsoft EXCEL Solver is used. In Chapter 5, The Econometric Software Package, "Regression Analysis of Time Series" (RATS) is used to estimate and analyze the time-varying conditional volatility and co-volatility of stock and Managed Futures indexes. In Chapter 6, Microsoft EXCEL is used again to calculate and analyze the moving average trading systems.

[14] See Section 3.2.1.1 Data Source.

Figure 3.1(A): Graphical representation of MSCI stock index for Canada, France, Germany, Japan, Switzerland, United States and United Kingdom - 1990 to 1998

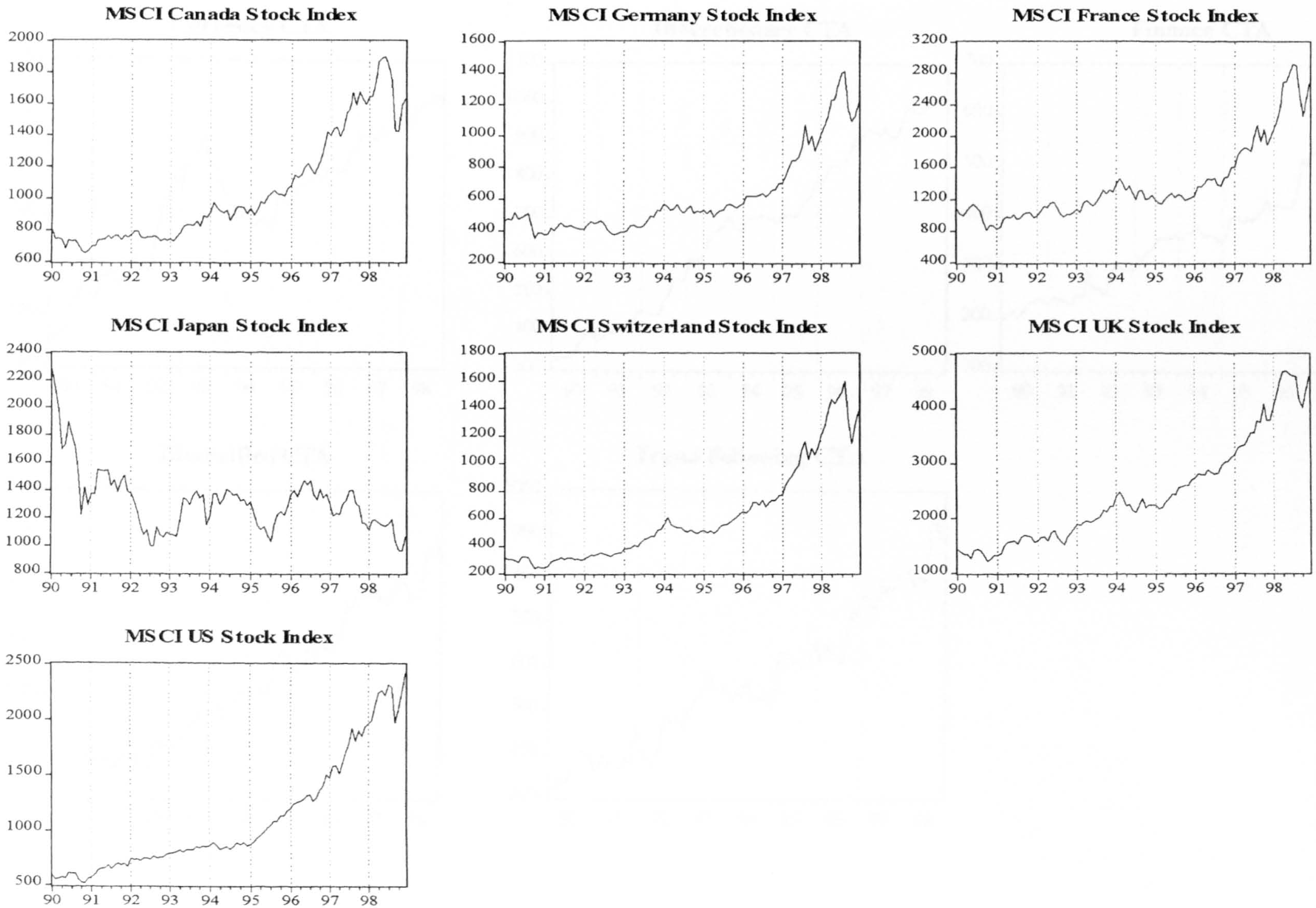


Figure 3.1(B): Graphical representation of Managed Futures index values for Currency CTA, Finance CTA, Diversified CTA, Discretionary CTA, Trend Following CTA - 1990 to 1998

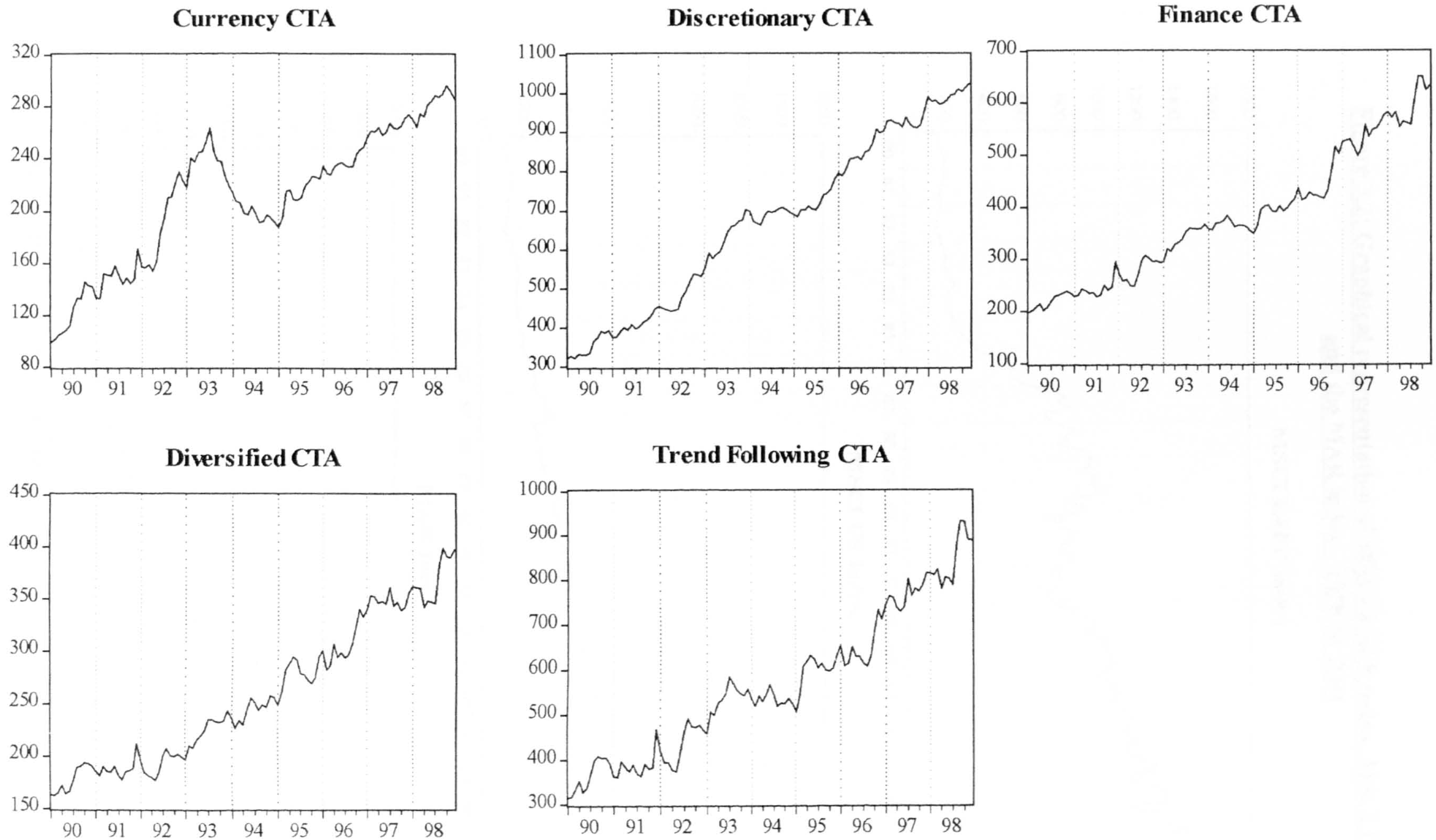


Figure 3.2: Graphical representation of MSCI EAFE index, MSCI US index and the MAR index - 1980 to 2001

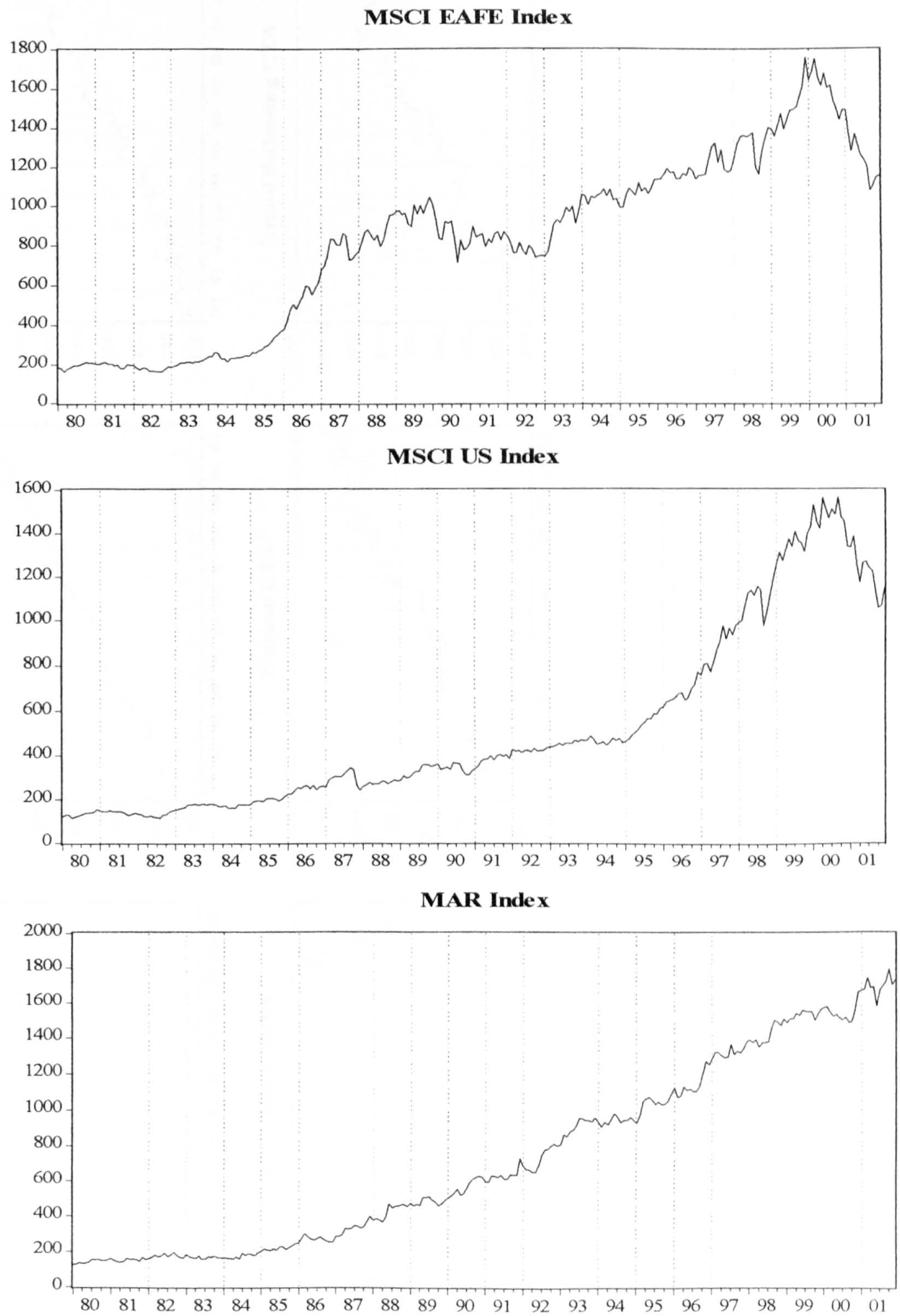


Figure 3.3: Graphical representation of MSCI EAFE index, MSCI US index and Managed Futures index for Currency CTA, Finance CTA, Diversified CTA, Discretionary CTA, Trend Following CTA- 1990 to 2001

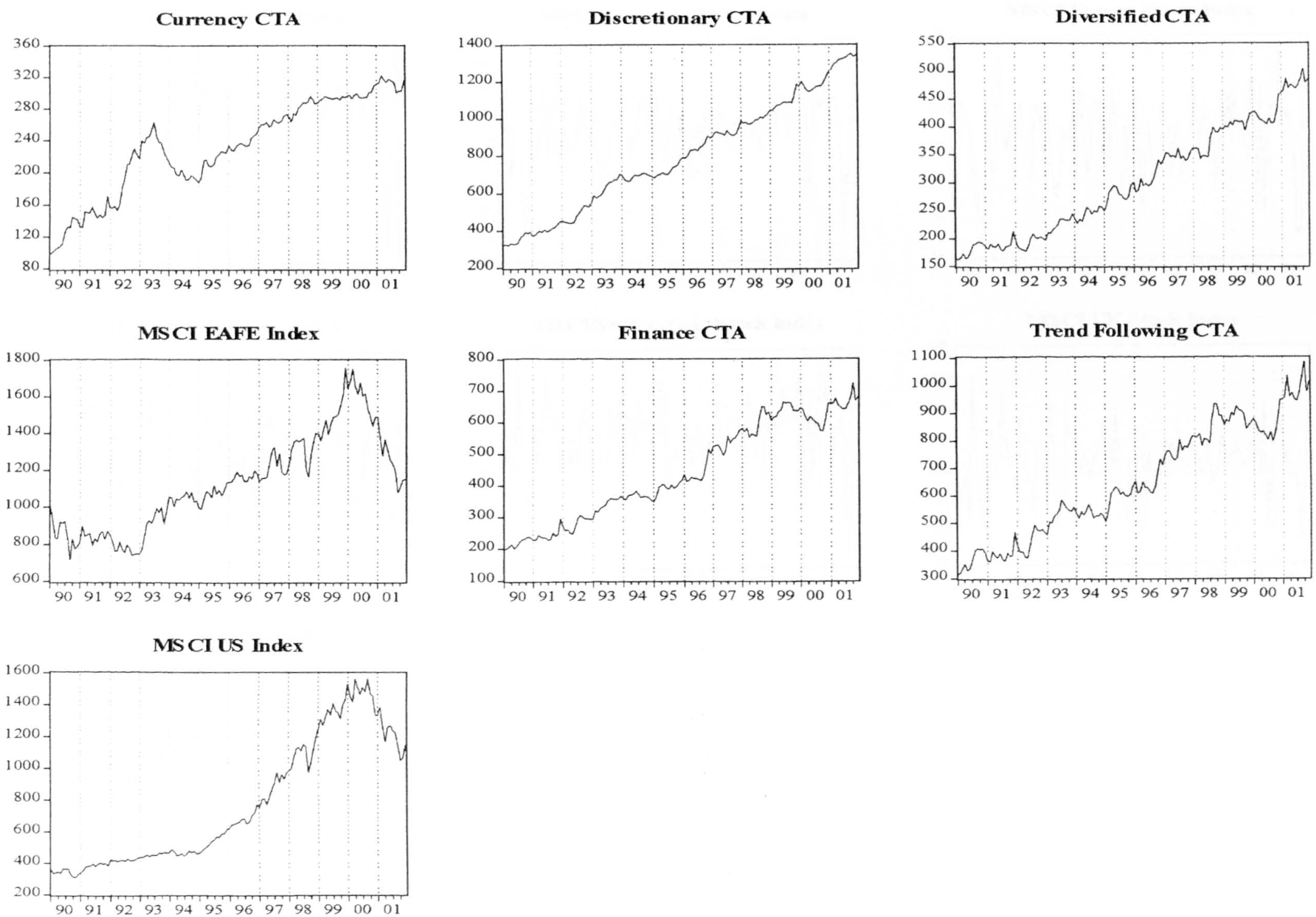


Figure 3.4(A): Graphical representation of MSCI stock index return (local Currency)
Canada, France, Germany, Japan, Switzerland, United States and United Kingdom - 1990 to 1998

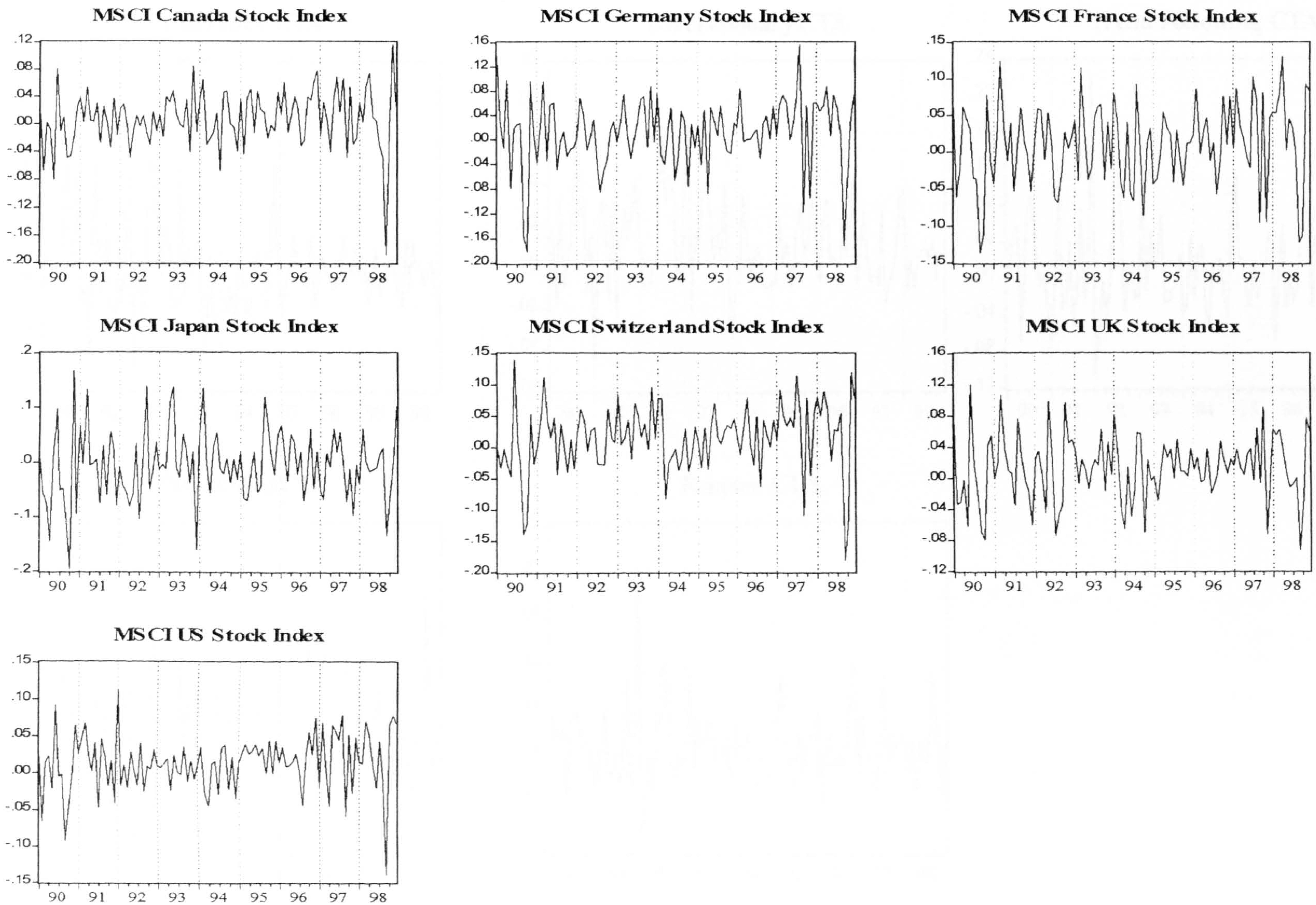


Figure 3.4(B): Graphical representation of Managed Futures index return (local Currency)
Currency CTA, Finance CTA, Diversified CTA, Discretionary CTA, Trend Following CTA - 1990 to 1998

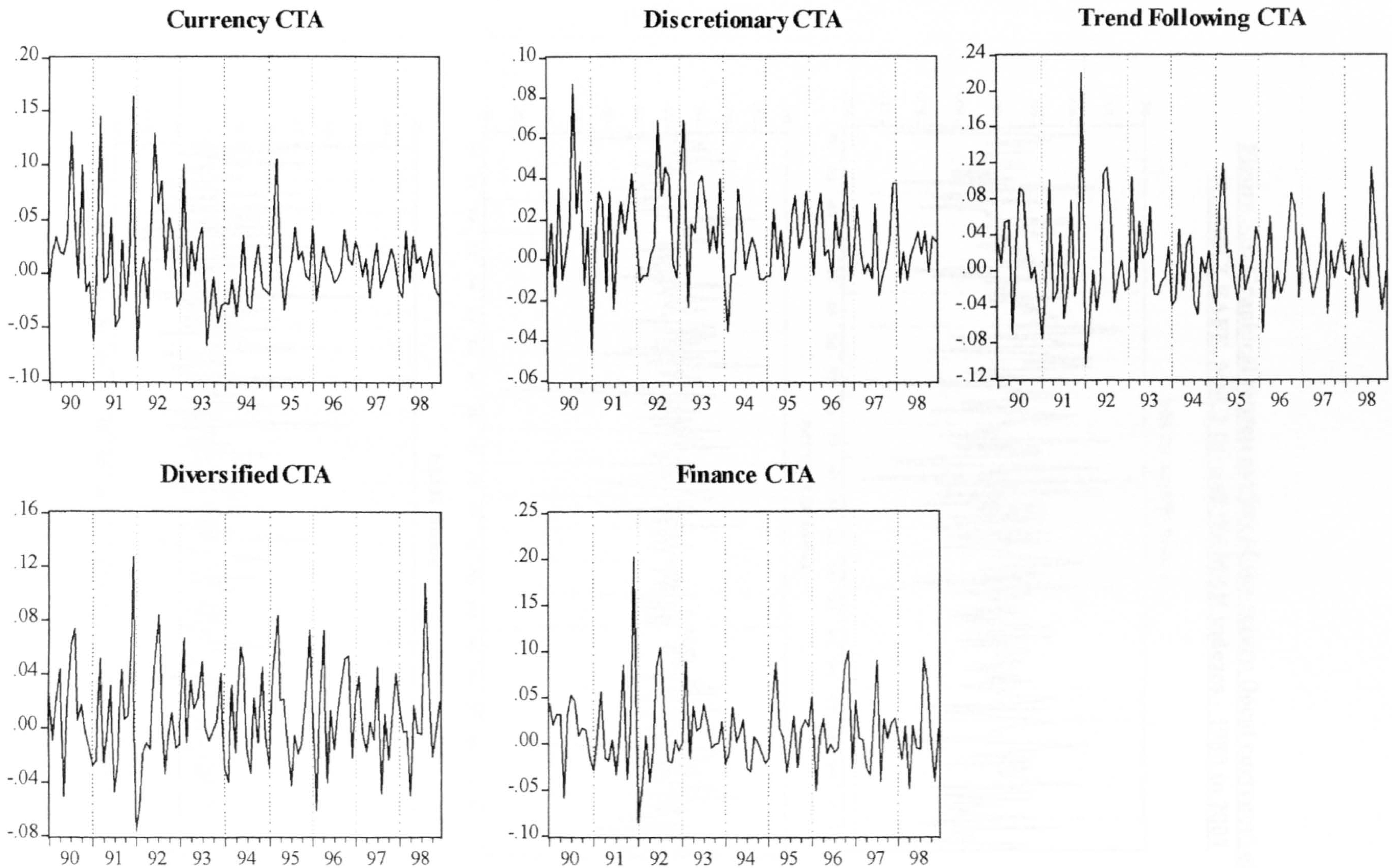


Figure 3.5: Graphical representation of the return (local currency) of the MSCI EAFE, MSCI US and the MAR indexes - 1980 to 2001

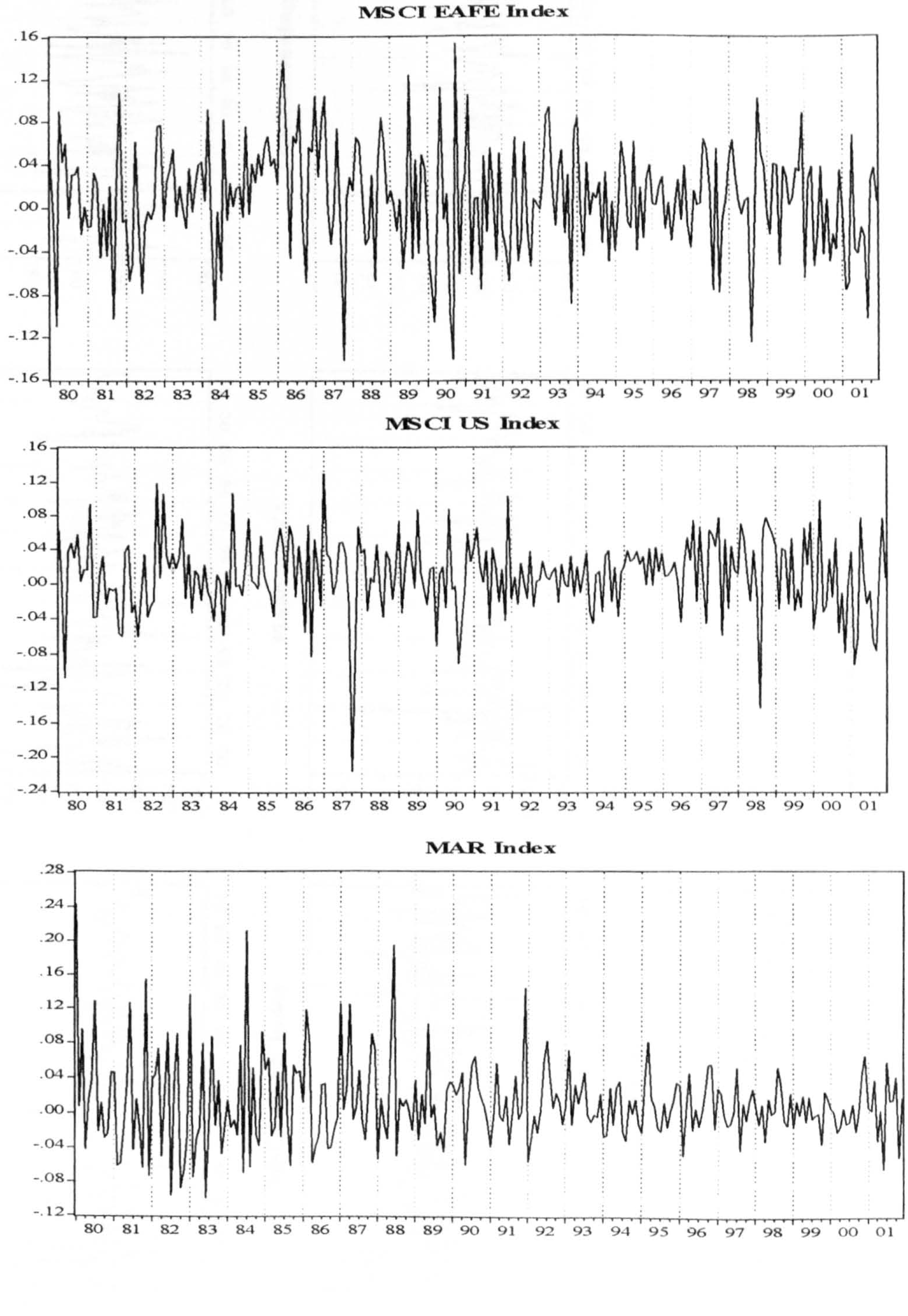
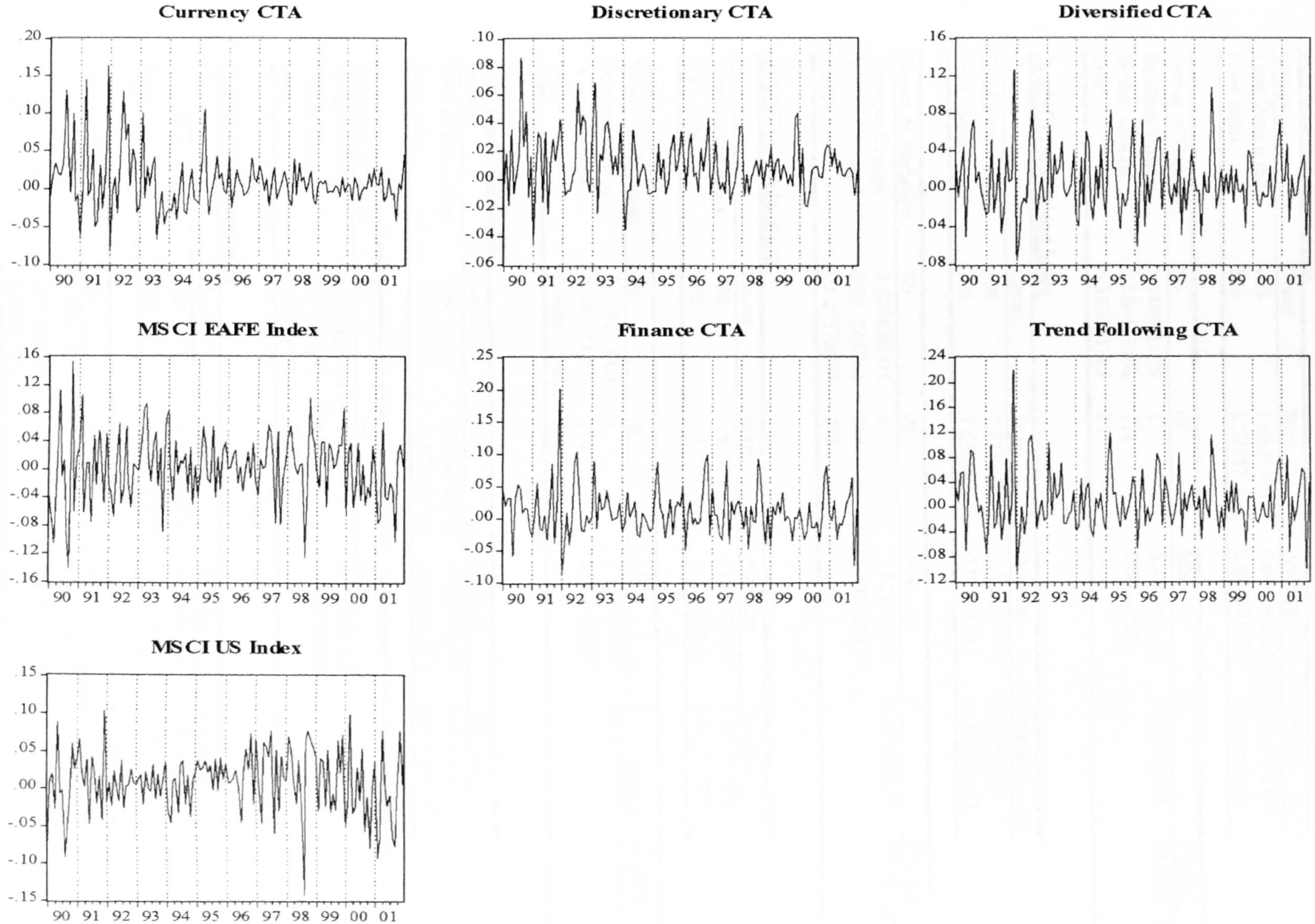


Figure 3.6: Graphical representation of the returns (local currency) of MSCI EAFE index, MSCI US index and Managed Futures index for Currency CTA, Finance CTA, Diversified CTA, Discretionary CTA, Trend Following CTA- 1990 to 2001



Appendix 3.1: F test statistical output for the variability of the returns for MSCI stock indexes (those reported as "price index" and those reported as "Total Returns") used for the empirical chapters 4, 5 and 6

ANOVA table for data used in chapter 4 (sample period: 1990 to 1998)

1) MSCI United States index

Groups	Count	Sum	Average	Variance
Total Return index	108	1.6303703	0.015096021	0.001505238
Price index	108	1.521871921	0.014091407	0.001488382

Source of Variation	SS	df	MS	F	P-value
Between Groups	5.44995E-05	1	5.44995E-05	0.036410461	0.848851239
Within Groups	0.320317266	214	0.00149681		
Total	0.320371765	215			

2) MSCI Switzerland index

Groups	Count	Sum	Average	Variance
Total Return index	108	1.731751139	0.016034733	0.00292119
Price index	108	1.65088255	0.01528595	0.002925032

Source of Variation	SS	df	MS	F	P-value
Between Groups	3.02765E-05	1	3.02765E-05	0.010357637	0.919032568
Within Groups	0.625545761	214	0.002923111		
Total	0.625576038	215			

3) MSCI Canada index

Groups	Count	Sum	Average	Variance
Total Return index	108	0.882739623	0.008173515	0.001712592
Price index	108	0.821622415	0.007607615	0.001712775

Source of Variation	SS	df	MS	F	P-value
Between Groups	1.72931E-05	1	1.72931E-05	0.010097087	0.920053952
Within Groups	0.366514305	214	0.001712684		
Total	0.366531598	215			

4) MSCI Japan index

Groups	Count	Sum	Average	Variance
Total Return index	108	-0.564040935	-0.005222601	0.004201216
Price index	108	-0.525287716	-0.004863775	0.004185369

Source of Variation	SS	df	MS	F	P-value
Between Groups	6.95283E-06	1	6.95283E-06	0.001658084	0.967557413
Within Groups	0.897364604	214	0.004193293		
Total	0.897371557	215			

5) MSCI Germany index

Groups	Count	Sum	Average	Variance
Total Return index	108	1.186631674	0.01098733	0.003175246
Price index	108	1.270945816	0.011768017	0.00332425

Source of Variation	SS	df	MS	F	P-value
Between Groups	3.29115E-05	1	3.29115E-05	0.010127388	0.919934491
Within Groups	0.695446032	214	0.003249748		
Total	0.695478944	215			

6) MSCI United Kingdom index

Groups	Count	Sum	Average	Variance
Total Return index	108	1.285121823	0.011899276	0.001790496
Price index	108	1.331249686	0.012326386	0.001820149

Source of Variation	SS	df	MS	F	P-value
Between Groups	9.85083E-06	1	9.85083E-06	0.00545655	0.941184049
Within Groups	0.386339007	214	0.001805322		
Total	0.386348858	215			

7) MSCI France index

Groups	Count	Sum	Average	Variance
Total Return index	108	1.147970454	0.010629356	0.003111502
Price index	108	1.136642019	0.010524463	0.003132638

Source of Variation	SS	df	MS	F	P-value
Between Groups	5.94136E-07	1	5.94136E-07	0.000190302	0.989006384
Within Groups	0.66812297	214	0.00312207		
Total	0.668123564	215			

ANOVA table for data used in chapter 5 (sample period: 1980 to 2001)

1) MSCI United States index

Groups	Count	Sum	Average	Variance
Total Return index	264	3.337550636	0.012642237	0.001959254
Price index	264	2.526397718	0.009569688	0.00195128

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.001246154	1	0.001246154	0.637331679	0.425038974
Within Groups	1.028470372	526	0.001955267		
Total	1.029716526	527			

2) MSCI EAFE index

Groups	Count	Sum	Average	Variance
Total Return index	264	2.713191496	0.010277241	0.002526604
Price index	264	2.221501419	0.008414778	0.002521648

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.000457877	1	0.000457877	0.181400266	0.670346846
Within Groups	1.32769032	526	0.002524126		
Total	1.328148197	527			

ANOVA table for data used in chapter 6 (sample period: 1990 to 2001)

1) MSCI United States index

Groups	Count	Sum	Average	Variance
Total Return index	144	1.612806287	0.011200044	0.001768212
Price index	144	1.291842837	0.008971131	0.001752599

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003577	1	0.0003577	0.203191658	0.652498422
Within Groups	0.503476064	286	0.001760406		
Total	0.503833764	287			

2) MSCI EAFE index

Groups	Count	Sum	Average	Variance
Total Return index	144	0.492785281	0.00342212	0.00241643
Price index	144	0.270699218	0.001879856	0.00241348

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.000171258	1	0.000171258	0.070915483	0.790200357
Within Groups	0.69067716	286	0.002414955		
Total	0.690848418	287			

Appendix 3.2: F-test statistical output for the variability of the returns for MSCI stock indexes (those reported "local currecy" and those reported as "UK pounds") used for the empirical chapters 4 and 5

3.2a) ANOVA table for data used in chapter 4 (sample period: 1990 to 1998)

3.2ai) MSCI stock indexes

1) MSCI Canadian stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	0.8216	0.0076	0.0017
UK Pounds Returns	108	0.9746	0.0090	0.0017

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0001	1	0.0001	0.0631	0.8019
Within Groups	0.3675	214	0.0017		
Total	0.3676	215			

2) MSCI France stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.1366	0.0105	0.0031
UK Pounds Returns	108	1.2541	0.0116	0.0031

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0001	1	0.0001	0.0204	0.8867
Within Groups	0.6716	214	0.0031		
Total	0.6717	215			

3) MSCI Germany stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.2709	0.0118	0.0033
UK Pounds Returns	108	1.4719	0.0136	0.0033

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0002	1	0.0002	0.0560	0.8131
Within Groups	0.7139	214	0.0033		
Total	0.7140	215			

4) MSCI Japanese stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	-0.0483	-0.0004	0.0042
UK Pounds Returns	108	-0.5253	-0.0049	0.0042

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0011	1	0.0011	0.2512	0.6167
Within Groups	0.8974	214	0.0042		
Total	0.8984	215			

Note:chapter 6 use data denominated in Local Currency Returns. The test for significant differences between UK£ Returns and Local Currency Returns is not relevant for this chapter.

5) MSCI Switzerland stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.9797	0.0183	0.0030
UK Pounds Returns	108	1.6509	0.0153	0.0029

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0005	1	0.0005	0.1704	0.6802
Within Groups	0.6287	214	0.0029		
Total	0.6292	215			

6) MSCI USA stock index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.7931	0.0166	0.0015
UK Pounds Returns	108	1.5219	0.0141	0.0015

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.2292	0.6326
Within Groups	0.3180	214	0.0015		
Total	0.3184	215			

3.2aii) CTA indexes

1) Currency CTA index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.4194	0.0131	0.0018
UK Pounds Returns	108	1.1464	0.0106	0.0017

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.1954	0.6589
Within Groups	0.3780	214	0.0018		
Total	0.3783	215			

2) Finance CTA index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.5724	0.0146	0.0017
UK Pounds Returns	108	1.3005	0.0120	0.0017

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.2050	0.6512
Within Groups	0.3574	214	0.0017		
Total	0.3577	215			

3) Diversified CTA index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.2610	0.0117	0.0014
UK Pounds Returns	108	0.9904	0.0092	0.0013

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.2513	0.6166
Within Groups	0.2887	214	0.0013		
Total	0.2890	215			

4) Discretionary CTA index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.4558	0.0135	0.0005
UK Pounds Returns	108	1.1837	0.0110	0.0005

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.7035	0.4026
Within Groups	0.1043	214	0.0005		
Total	0.1046	215			

5) Trend Following CTA index

Groups	Count	Sum	Average	Variance
Local Currency Returns	108	1.4792	0.0137	0.0025
UK Pounds Returns	108	1.2074	0.0112	0.0025

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0003	1	0.0003	0.1356	0.7130
Within Groups	0.5395	214	0.0025		
Total	0.5399	215			

3.2b) ANOVA table for data used in chapter 5 (sample period: 1980 to 2001)

3.2bi) MSCI Stock index

1) MSCI US index

Groups	Count	Sum	Average	Variance
Local Currency Returns	264	2.5264	0.0096	0.0020
UK Pounds Returns	264	3.1260	0.0118	0.0025

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0007	1	0.0007	0.3030	0.5823
Within Groups	1.1821	526	0.0022		
Total	1.1828	527			

2) MSCI EAFE index

Groups	Count	Sum	Average	Variance
Local Currency Returns	264	2.2215	0.0084	0.0025
UK Pounds Returns	264	2.2857	0.0087	0.0023

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0000	1	0.0000	0.0032	0.9548
Within Groups	1.2752	526	0.0024		
Total	1.2752	527			

bii) CTA index

3) MAR index

Groups	Count	Sum	Average	Variance
Local Currency Returns	264	3.1688	0.0120	0.0024
UK Pounds Returns	264	3.7381	0.0142	0.0030

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0006	1	0.0006	0.2295	0.6321
Within Groups	1.4070	526	0.0027		
Total	1.4077	527			

Appendix 3.3: Illustration of the hedging process for foreign currency based assets that use the currency forward contract (Adapted from Eun & Resnick (1988), pg 202 to 204)

Assume a US investor[1] dealing with foreign investments, then the dollar rate of return under the hedging strategy is given by:

$$\overline{R}_{i\$}^{H} = [1+E(\overline{R}_i)](1+f_i)+[\overline{R}_i - E(\overline{R}_i)](1+\widetilde{e}_i)-1 \qquad (3.1)$$

Expanding (3.1) gives

$$\overline{R}_{i\$}^{H} = \overline{R}_i + f_i + \overline{R}_i\widetilde{e}_i + E(\overline{R}_i)(f_i - \widetilde{e}_i) \qquad (3.2)$$

Where $E(\overline{R}_i)$ is the expected rate of return on the ith foreign stock market in terms of the foreign currency, $\widetilde{e}_i$ is the rate of appreciation of the local currency against the dollar, and f_i is the forward exchange premium.

Equations (3.1) and (3.2) clearly show that foreign currency based assets can be hedged only to the extent that the foreign currency proceeds amount (i.e., after converting into US Dollar) is within expectation. The unexpected foreign currency proceeds will therefore have to be converted into US Dollar using the uncertain future spot foreign exchange rate.

[1] Eun & Resnick (1988) illustrates the case of the hedging process of a US investor investing in foreign assets. This serves as an relevant example to us because we are considering the case of UK investor in the same hedging process as that of the US investor in Eun & Resnick (1988)'s case, except that currency is converted into British Pound in our case, instead of US Dollar as in Eun & Resnick (1988).

Eun & Resnick (1988) further reduce (3.2) into the following being the fact that the 3rd and the 4th term in the equation are small in magnitude.

$$\overline{R}_{i\$}^{H} \approx \overline{R}_{i} + f_i \qquad (3.3)$$

To make sure that it is appropriate to use (3.3) as an approximation for (3.1) and (3.2), Eun & Resnick (1988) calculate the mean-return vector and variance-covariance matrix using both equations, with an aim to assess the size of estimation errors. The historical mean return was used for $E(\overline{R}_i)$ in equation (3.3). Eun & Resnick (1988) found that the approximation error resulting from using equation (3.3) is indeed negligible. Specifically, the magnitude of absolute error relative to the precise value was found to be only about 2 percent for the mean returns and less than one percent for the variance-covariance, with exception of a few entries. Eun & Resnick (1988) explain that, on omitting $\overline{R}_i\widetilde{e}_i$, which is customary in the literature, together with $E(\overline{R}_i)(f_i - \widetilde{e}_i)$ was found to be justifiable on empirical grounds.

The explanation of the hedging process by Eun and Resnick (1988) and the subsequent omission of terms relating to the hedging process as shown by the expression in (3.2) has helped simplified the computation of the hedged returns (i.e., using the forward contract) of foreign asset (in local currency) to that of the form found in (3.3).

Chapter 4

Asset Allocation with Managed Futures: Evidence from a Downside Risk Analysis

4.0 Introduction to the Chapter

In this chapter, the primary objective is to provide an empirical analysis of the potential incremental portfolio returns and/or risk reduction benefits to investors arising from the opportunity to allocate a proportion of their total investment funds to Managed Futures. The analysis has been based on the assumption that Managed Futures investments can be viewed as a distinct asset class that, for asset allocation decisions, may be treated in exactly the same way as any other traditional asset class such as equities, bonds, property, etc. The validity of the analysis into the incremental benefits of Managed Futures is also largely dependent upon the ability to develop a realistic model of investor objectives and decision processes. Recent research by Fung & Hsieh (2001) into the trend-following strategies adopted by hedge funds and Managed Futures traders has shown a significant positive skewness in returns. Given the large body of behavioural evidence that indicates a marked and persistent aversion to losses amongst investors, Fung and Hsieh's (2001) positive skewness results have important implications in respect of simulating investor decision criteria and asset allocation strategies. This empirical study adopts a Lower Partial Moment approach as the main methodology as it provides a more general approach to understanding the relationship between underlying assets' returns' skewness and investor's asymmetric downside risk concerns. The primary focus will be on testing for portfolio performance arising from using the Lower Partial Moment approach and the Minimum Variance approach to allocating Managed Futures and MSCI stock indexes to investor's portfolios. Portfolio performance will then be compared across these two approaches. This analysis will be undertaken from the perspective of a UK investor.

4.1 Literature Review on the Development and Empirical Evidence on the use of Lower Partial Moments

4.1.1 Risk Measures of Variance and Below-Target Variance

Since the publication of Markowitz's (1959) seminal paper on portfolio diversification, numerous studies have adopted and extended Markowitz's ideas to analyse the implications for a wide range of portfolio selection and portfolio performance issues. The vast majority of these subsequent analyses have followed Markowitz's favoured symmetric mean-variance approach to risk and have, therefore, restricted their attention to the first two moments of the return distribution: the mean and variance. Sharpe (1964) and Lintner (1965) are two important early pioneers of what is now the standard framework for analysing the risk/return trade-off. Though not as popular as viewing risk solely in term of variance, some researchers have explored and/or adopted the notion of risk as variability (variance) below a certain target level return (more commonly known as downside risk). Research in this area includes the contributions of Harlow (1991) and Nawrocki (1999), amongst others.

Markowitz (1959) was, of course, aware of the behavioural assumptions embedded in analyses based on variance; namely, that investors are equally anxious to eliminate both extremes of the return distribution. He also suggested that analyses of investor preferences based on semi variances, which assumes that investors will concentrate largely on reducing losses, i.e., the decision criterion is on reducing losses below target mean returns, could provide a more accurate model of investor decision making. The analysis of portfolio risk based on semi variance, by concentrating on reducing losses below target mean returns, produces portfolio allocations that minimise the probability of below target means returns. It was due primarily to the complexity and the costs involved in the computation of semi-variance analyses that led Markowitz (1959) to drop the semi-variance as his preferred risk measure and to concentrate instead on his now famous mean-variance approach to portfolio theory. The limitations of risk measures based upon below target variance in Markowitz (1959) were also noted in Harlow (1991) and Nawrocki (1999). Even so, Markowitz (1959, pg 194) commented that the superiority of variance with respect to costs, convenience and familiarity does not, and may not in the future, preclude the use of semi-variance.

The issue of variability of below target returns (or semi-variance) has, however, been investigated by authors such as Nawrocki (1999) or Harlow (1991) as a special case of variability of below target returns and this research has stimulated interest in several classes of alternative risk measures. One of the most enduring ideas involves focusing on the tail of the relevant distribution of returns, i.e., the returns below some specific threshold level or target rate. Risk measures of this type are referred to as "Lower Partial Moments" because only the left-hand tail (i.e., probability of under-achieving a threshold return) of the return distribution is used in calculating risk[1]. As will be discussed at later sections, the Lower Partial Moment is related to skewness, but it cannot be identified simply as the "third moment" (skewness) itself. And this

[1] See Appendix 4.1 for a simple illustration of the computation of LPM.

naturally implies that the formula for computing the 'Lower Partial Moment' is different to that of computing 'skewness'. [2]

Harlow (1991) suggested that the theoretical assumptions necessary to support variance as the primary risk measure are in fact rather restrictive and often not consistent with investors' actual perceptions of risk. He argues that most executives and institutional investors in the industry would perceive risk as primarily the probability of not achieving a minimum level of return. He further stresses that this argument is also supported by researchers in finance, economics and psychology, who over the past three decades, have observed that individuals do indeed view return dispersions in an asymmetric manner; i.e., potential losses weigh more heavily than gains of the same magnitude. Similar arguments can be found in Nawrock (1999), Persson (2000) and Fischmar & Peter (1991).

The development of useful portfolio selection tools from this initial idea of Lower Partial Moment, has, however taken some time. As Harlow (1991) points out, not a lot of progress had been achieved since Markowitz's (1959) paper first raised the issue of alternative risk measures in addition to variance that investors could adopt to diversify the overall risk of their investment portfolios. Markowitz (1959) concluded that the most theoretically robust measure was in fact the semi variance (i.e., the

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[2] One other way to deal with portfolio selection with skewness is to use the Polynomial Goal programming (PGP) method. In constructing PGP, the standard statistical moment of distributions, where investors exhibit a preference for higher values of odd moments (mean return, skewness) and a dislike for higher values of the even moments (variance, kurtosis) (Scott and Horvath 1980), is considered. Here, multiple objectives related to the three moments are defined, i.e., to maximize expected rate of return, minimize variance and maximize skewness. This is then solved by PGF, which then allow a simultaneous solution of a system of multiple objectives, rather than only of a single objective. This is different from the LPM approach to deal with portfolio with skewness. This is because unlike LPM approach, PGP approach do not consider only the left-hand tail (i.e., left to some threshold level) of the return distribution at the first instance. Therefore, PGP approach is still very much solving for portfolio with skewness assuming variance as a risk measure. In this context, skewness, in combination with the two moments reflect the attitude towards both the upper and the lower part of the distribution. LPM approach is also trying to solve for skewness within portfolio, the underlying assumption, however, is about using variation of return below target level as a risk measures. See Lai (1991), Chunhachinda, Dandapani, Hamid & Prakash (1997) and Prakash, Chang & Pactwa (2003) for more recent applications of PGP used for solving portfolio selection problem with skewness.

expected value of the squared negative deviations about a specified 'target' rate of return). However, due to the (then) computational problems associated with calculating the semi variance statistic, Markowitz adopted variance as the risk measure in his analysis. As a result, much of the initial research in finance focused on the issues surrounding the use of the, very much simpler, mean variance framework.

Markowitz (1959) used mean returns, variances and covariance to derive an efficient frontier where every portfolio on the frontier maximises the expected return for a given variance and which minimises the variance for a given expected return. According to Markowitz (1959), the importance of portfolio selection for investments purposes is that it involves investor making a trade off between risk and return, and the assumption that the investor has a quadratic utility function. Nawrocki (1999) comments that while the investor's sensitivity to changing wealth and risk is supposedly derived from the investor's utility function, the elements that determine a utility function for a human being are, however, rather obscure.

Nawrocki (1999) points out that another seminal paper on portfolio theory was Roy (1952). Roy's purpose was to develop a practical method for determining the best risk-return trade-off as he did not believe that a mathematical utility function could be derived for an investor. Roy (1952) states that investors generally prefer to operate under the principal of safety first, that is they will wish to set some minimum acceptable return that will maximise the probability of conserving their principal (initial investment). Roy called the minimum acceptable return the disaster level and the resulting technique is called the Roy safety first criterion. Roy stated that the investor would prefer the investment with the smallest probability of going below the disaster level or target return. By maximising a reward to variability ratio, $(r - d)/s$, the investor will choose the portfolio of the lowest probability of going below the disaster level, ***d***, given a expected mean return, ***r***, and a standard deviation, ***s***.

Roy's concepts of an investor preferring to operate under the principal of safety first when dealing with risk, has been influential in the subsequent development of downside risk measures. The reward to variability ratio allows the investor to minimise the probability of the portfolio falling below a disaster level, or for our purposes, a target rate of return.

Nawrocki's (1999) review of Markowitz's (1959) contribution, commented that the latter also recognised the importance to investors of avoiding portfolio returns below a disaster level. In fact, Markowitz (1959) realised that investors are interested in minimising downside risk for two reasons: (1) only downside risk or safety first is relevant to an investor and (2) security distributions may not be normally distributed. Therefore a downside risk measure would help investors make proper decisions when faced with non-normal security return distributions. Markowitz (1959) explains that when distributions are normally distributed, both the downside risk measure and the variance provide the correct answer. However, if the distributions are not normally distributed only the downside risk measure provides the correct answer. Markowitz (1959) provides two suggestions for measuring downside risk: a semi variance computed from the mean return or below-mean semi variance (SV_m) (shown by equation 4.1 below) and a semi variance computed from a target return or below-target semi variance (SV_h) (shown by equation 4.2 below). The two measures compute a variance using only the returns below the mean return (SV_m) or below a target return (SV_h). Since only a subset of the return distribution is used, Markowitz called these measures partial or semi- variances.

$$SV_m = \frac{1}{K}\sum_{t=1}^{k} [\text{Max}\,(0, (E\text{-}R_t)]^2 \qquad \text{below-mean semi variance} \qquad (4.1)$$

$$SV_h = \frac{1}{K}\sum_{t=1}^{k} [\text{Max}\,(0, (h\text{-}R_t)]^2 \qquad \text{below-target semi variance} \qquad (4.2)$$

where R_t is the asset return during time period t, K is the number of observations, h is the target rate of return and E is the expected mean return of the asset's return. The maximisation function, *Max*, indicates that the formula will square the greater of the two values, 0, or $(h - R_t)$.

As mentioned above, after proposing that the semi variance measure was probably superior, Markowitz (1959) nevertheless concentrated on the variance measure due to its relative computational simplicity. For example, semi variance optimisation models using a semi-covariance matrix require twice the number of data inputs of the variance model. Nevertheless, research on semi variance continued throughout the 1960s and early 1970s. This includes, for example, Quirk and Saposnik (1962) who applied measurable utility theory to the problem of choices considering the probability distribution of income, and the preference orderings that more income to be preferable to less income. Their aim was to investigate the implications of these assumptions for the Von Neumann-Morgenstern preference orderings (that underlies the mean variance efficient portfolios set) over probability distribution of income. They then defined and developed a very natural concept of admissibility related to their assumptions and show that mean variance efficient portfolios may be inadmissible, even when compared with portfolios that are not in the efficient frontier. But, they observed that the mean-semi-variance model is not subjected to this drawback.

Nawrocki (1999) commented that Markowitz (1959) measured skewness by taking the variance and then dividing it by the below-mean semi variance (SV_m). If the distribution is normally distributed then the semi variance should be one-half of the variance. If the ratio is equal to 2, then the distribution is symmetric. If the ratio is not equal to 2, then there is evidence that the distribution is skewed or asymmetric. Skewness is a measure of the symmetry of the distribution. If there is no skewness, then the distribution is symmetric. When the skewness of an asset returns distribution is negative, and then downside returns have a larger magnitude of returns than the upside returns, i.e. losses when they occur will tend to be large losses. When the skewness of the distribution is positive, then upside returns have a larger magnitude than the downside returns, i.e., when losses occur, they will be smaller and when gains occur, they will be greater.

Nawrocki (1999) claims that research and subsequent developments into downside risk measures and Lower Partial Moment models progressed significantly following the publication of the Bawa (1975) and Fishburn (1977) studies. Bawa (1975) defined the Lower Partial Moment as a general family of below-target risk measures, one of which is the below-target semi variance. The Lower Partial Moment describes below-target risk in terms of risk tolerance. Given an investor risk tolerance value n as the general measure, the Lower Partial Moment, is defined as follows:

$$LPM(n,h) = \frac{1}{k}\sum_{t=1}^{k}[Max\,(0,(h - R_t)]^n, \qquad (4.3)$$

where K is the number of observations, h is the target return[3], n is the degree (or the risk tolerance value) of the Lower Partial Moment, R_t is the return for the asset during time period t, and *Max* is a maximisation function which chooses the larger of two numbers, 0 or $(h - R_t)$. It is the "n" value that differentiates the Lower Partial Moment from the SV_h. Semi-variance calculations restricts the value of "n" only to 2. However, for Lower Partial Moment, the deviations can be raised to the "n" power and the "n" root can even be computed. There is no limitation to the value that "n" can take in the Lower Partial Moment. Indeed, the "n" value does not even have to be an integer. It can also be a real number.

4.1.2 Stochastic Dominance and Its Application to Lower Partial Moment

Utility function analyses focus on the decision making and choice selection processes of investors. They form the theoretical underpinnings for much of modern financial modelling.

The basic economic properties of utility functions[4] formulate utility functions in terms of end of period wealth. The properties state that more wealth is always preferred to less wealth. If utility increases as wealth increases, then the first derivative of utility, with respect to wealth, is positive. Thus, the first restriction placed on the utility function is a positive first derivative with respect to wealth. The second property of a utility function is an assumption about the investor's attitude for risk. For this, there are three possibilities: the investor is averse to risk, the investor is neutral to risk or the investor seeks risk.

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[3] The target value is assumed to be "zero" in the thesis. The selection of the target value is arbitrary. Alternatively, risk free rate can also be used as target value, but as the other empirical chapters did not consider using risk free rates (particularly for Chapter 6, in which returns were considered based upon currency conversion methods), the target value is therefore decided to be fixed at "zero" for this chapter.

[4] The explanation of the utility functions is referenced from Chapter 8 of Elton and Gruber (1991).

Existing evidence in the literature shows that investors are more sensitive to losses than to gain, see for example, Nawrocki (1999) and Harlow (1994). This affects the investor's attitude to risk and it means that investors are not likely to be risk averse throughout the possible range of the return distribution and will therefore exhibit risk seeking behaviour or be risk neutral in special situations.

The Lower Partial Moment does not capture investor's preference on the upside derivation from the target rate returns. For the below target returns, as investors are keen to minimise on this derivation, it is therefore a risk seeking behaviour. To sum up, utility function, within a lower partial moment framework, differs between below the target and above the target rate return, see, for example, Fisburn (1977) and Cumova and Nawrocki (2003) for more details.

Bawa (1975) observed that decision making of investors under uncertainty may also be viewed as choices between alternative probability distributions of returns of different assets. While an individual might choose between alternatives in accordance with a consistent set of preferences, such selection in most cases is not possible. The well-known theoretical and empirical difficulties associated with specifying and eliciting utility functions from human subjects are made all but impossible due to "bounded rationality", i.e., the limitations of human information processing capabilities. This follows that the assumptions or restrictions imposed on explaining investor's preferences, in term of utility functions, might not be as adequate as it appears to show.

The alternative[5] considered here are the rules of Stochastic Dominance ("SD" thereafter), a concept developed very early last century (cf. references cited by Kroll &

[5] It is clear that the use of stochastic dominance arises primarily because of the limitation associated with utility functions/theory. Integration of the two concepts could be an avenue for future research.

Levy, 1980) but not introduced into economic theory before the late 1960s (Hadar & Russell, 1969; Hanoch & Levy, 1969; Rothschild & Stiglitz, 1970; Whitmore, 1970). The central idea behind the SD approach is that it tries to simplify the decision problem by sorting out dominated alternatives (Unser, 2000). Basically, individuals are still believed to maximize their subjective utility but they only have to specify their utility function in a very rough manner, i.e. the knowledge of a concrete function is being replaced by assumptions about classes of functions or properties of the functions.

And one way in which these dominated alternatives could be sorted is to go through the "first order stochastic dominance" (thereafter known as FSD), "second order stochastic dominance" (thereafter known as SSD) and the "third order stochastic dominance" (known as TSD thereafter). These three orders of stochastic dominances take into account the pair-wise comparison of the cumulative probability density (i.e., the likelihood of obtaining a given return or less) functions of two underlying investment returns, say, F and G. A certain set of criteria, following FSD, SSD and TSD would need to be satisfied in order for, say, F to dominate G[6].

Unser (2000) explained that the ordering of preference from applying the FSD, SSD and TSD can be shown and is identical to the order generated by maximization of utility for specific classes of utility functions[7]. Elton & Gruber (1991) explain the nature of investor's preference underlying the utility of each order of stochastic dominance[8]. They explain that if F consistently dominates G for the three orders of stochastic dominance, then an investor is said to preferring more to less (FSD). In addition to that,

[6] See Appendix 4.2 for a mathematical proof of the three order stochastic dominance, adopted from Elton & Gruber (1991).
[7] The simple proof in Appendix 1.2 from Elton & Gruber (1991) about the FSD, SSD and the TSD incorporate utility function as part of their analysis and discussion.
[8] This investor's preferences are explained more in details with the incorporation of utility function in Appendix 4.2.

he is also risk averse (SSD); on top of that, he also has decreasing absolute risk aversion (DARA) and the preference for positively skewed distributions (Arditti, 1967) (TSD)[9].

Unser (2000) explains that the broad conception of risk could also be made more operational if it is possible to find appropriate risk measures. Possible risk measures are the moments or the pattern of return series characterizing a probability distribution. Using all the moments of a distribution in making a decision yields the same result as maximizing its expected utility. As a consequence, expected utility is a function of all moments of a distribution. This means that an ordering of alternatives according to stochastic dominance rules implies also an ordering according to the moments of a distribution or distributional pattern of return series. The decision task can therefore be simplified substantially if it is possible to focus on a few moments and thereby still be maximizing expected utility.

By redefining probability distribution of returns suited to the distributional pattern or moments of return series following that of the Lower Partial Moment, Bawa (1975) shows that such arbitrary probability distributions such as the Mean-Lower Partial Moment (Variance) rules are in accordance with the principles of first, second and third order Stochastic Dominance. This naturally satisfies the Lower Partial Moment criteria for describing investor's preference or utility underlying these three orders of stochastic dominance[10].

[9] See Appendix 4.3 for a simple proof that explains the relationship between decreasing absolute risk aversion and preference for positive skewness.
[10] See Frowein, W (2000) for an example of mathematical proof showing LPM satisfying the principles of the first, second and third order stochastic dominances. Following the satisfaction of the principles, this then follows that the description of investor's preference for the first, second and third order stochastic dominance principle as shown in Appendix 4.2 is applicable to the case for Lower Partial Moment.

4.1.3 Empirical Evidence on the use of Lower Partial Moment

Bawa (1975) defined "Lower Partial Moment" as a general family of below-target risk measures, one of which is the below-target semi-variance. Fishburn (1977) and Nawrocki (1992) argue that the Lower Partial Moment algorithm is general enough for it to be tailored to the utility function of a specific investor. Conceptually at least, an n-degree [the value of "n" in (4.3)] Lower Partial Moment algorithm provides both benefits of stochastic dominance: a general utility function and no restrictive assumptions about the probability distribution of security rates of return. Fishburn (1977) also comments that the flexible n-degree Lower Partial Moment shared many of the attractive features of the mean-semi variance model, as discussed in Markowitz (1959). This is the case when the value of "n" in Lower Partial Moment is able to flexibly adjust. Fishburn (1977) argues that different values of "n" (in 4.3) would approximate wide variety of attitudes, towards risks of falling below a certain target level of returns, while Unser (2000) claims that varying the value of "n" will determine the weights investors place on the deviation below returns.

By varying the value of 'n', Lower Partial Moment gives different varieties of risk attitudes. This is because the larger the value of "n", the smaller will be the values of Lower Partial Moment. This then indicates a lower downside risk or risks of variability of returns below target level or vice versa if the value of "n" is reduced. This is how the adjustment of "n" could alter Lower Partial Moment, and subsequently reflect the risk appetite of investors. Nawrocki (1999) commented that the adjustment of "n" makes Lower Partial Moment more flexible and hence a superior choice for risk measure comparing with variance and semi-variance measures, when the value of "n" is only restricted to "2".

Following the observation of Fishburn (1977) regarding the adjustment of "n" (as in 4.3) giving it flexibility to LPM and giving rise to different attitudes to risks, Nawrocki (1990) explores the effect this has on the skewness of a portfolio. Nawrocki (1990) uses 30 years (1958 to 1987) of monthly data with portfolios revised every 2 years using 48 months of estimation periods, with a sample of 150 stocks. Using R/SV_h (i.e., Return-to-Semi-variance-at-target-rate-of-zero) as a performance measurement tool, he reports the skewness results with the average of portfolio with 5, 10 & 15 stocks. He finds that for degree of "n" up to 5, R/SV_h ratio remains above 0.2, the skewness values are statistically significant. As the skewness values increased from 0.34 (n = 5.0) to 0.6 (n=10), the R/SV_h ratio reduced from 0.2 to 0.18, indicating a decrease in the risk-return performance as skewness increases. Table 4.1 below shows the results from Nawrocki (1990).

Table 4.1: Out-of-sample skewness results from Nawrocki (1990)

LPM Degree (n)	Skewness	R/SVt Ratio
0.0	.1122	.1712
1.0	.0756	.1984
1.2	.0719	.2117
1.4	.0713	.2221
1.6	.0833	.2110
2.0	.1110	.2089
2.8	.1934	.2186
3.0	.2115	.2155
4.0	.2771*	.2098
4.6	.3093*	.2044
5.0	.3446*	.2005

Table 4.1(con't) : Out-of-sample skewness results from Nawrocki (1990)

LPM Degree (n)	Skewness	R/SVt Ratio
6.0	.4287*	.1905
7.0	.4975*	.1848
8.0	.5413*	.1854
9.0	.5855*	.1825
10.0	.6129*	.1794
EV Optimal	-0.0546	.1383

* - Indicates statistical significance at two standard deviations (5% 2-tail test)

Using R/SV_h as a form of frame of reference, Nawrocki (1990) notes that while portfolio managers can increase the skewness of a portfolio, this, however, is likely to be at the cost of reduced returns. He concluded that an algorithm employing the Lower Partial Moment framework appears to be a viable alternative to purchasing puts, synthetic puts, or other insurance strategies.

Two other examples of empirical studies that make use of the concept of Lower Partial Moment, but not to the extent of adjusting for the value of "n" (in 4.3) are Harlow (1991) and Stevenson (2001). Harlow (1991) considers the use of a global asset allocation problem relevant to many portfolios managers. His fully currency-hedged portfolio includes equity and fixed income markets assets from 11 countries, for a period of 11 years covering the period from January 1980 to December 1990. Using an estimated 60 monthly observations for all the 11 assets studied, he derived the weights needed for two portfolios, using respectively the mean variance and Lower Partial Moment framework. His results show that asset allocation in a downside-risk framework provides an attractive and powerful alternative to the traditional mean-variance approach. He explains that the differences between the downside risk and mean variance approaches arise because returns are not strictly normally distributed, as the sample he used shows. Harlow (1991) draws attention to the differences between the portfolio returns generated by using Lower Partial Moment and the Minimum Variance approach documented in his paper, and these appear to indicate potential benefits may be derived from closely examining the methodology of portfolio construction and using the distribution of returns as an input.

Stevenson's (2001) study provides preliminary evidence regarding allocating investment funds to emerging markets within a downside risk framework. He analyses a total of 15 emerging markets and 23 developed markets over the period from 1988 to 1997 on a monthly basis. He estimates a portfolio using the first 5 years of monthly data, constructed on the basis of the mean variance and Lower Partial Moment risk measures and tests them out of sample, holding for 5 years continuously. Like Harlow (1991), Stevenson (2001) uses downside risk measures, in the context of constructing minimum risk portfolios, and shows a significant improvement in out sample portfolio performance.

4.2 Empirical Research, Objective, Data and Contributions for analysing Downside Risk

The empirical research framework adopted in this chapter closely follows that of Nawrocki (1992). Nawrocki (1992) investigated two topics of Lower Partial Moment theory: the size and composition of portfolio selected by an n-degree (refer to "n" in (4.3) as well) Lower Partial Moment algorithm, and the effect of varying "n" on the expected performance of the investment portfolio.

Most of the existing research, e.g., Edwards & Liew (1999) and Edwards & Park (1996), on the performance of portfolio that used Managed Futures has generally used the criterion of the maximisation of the Sharpe ratio as the basis of the optimisation algorithm. And that is then used to allocate Managed Futures to an existing optimised portfolio of traditional asset classes. The empirical study of this chapter takes a different approach by using the Lower Partial Moment method for asset allocation decisions involving Managed Futures. As will be shown later, the Managed Futures' returns distribution reveals some level of significant positive skewness. Therefore, evidence provided on asset allocation in a downside risk framework will be more relevant, when Managed Futures and the various MSCI stock indexes are used within the same portfolio. This is then compared with an alternative allocation that used the Minimum Variance approach.

The aim of the empirical analysis is to evaluate the effectiveness of downside risk approaches to the asset allocation process when Managed Futures instruments are used as part of a MSCI stock indexes portfolio. This analysis is presented from the perspective of the UK investors with an objective to protect their internationally diversified portfolio from downside risk. This section will first discuss the computational algorithm of the Lower Partial Moment (thereafter, "LPM") that is to be used in this chapter for empirical analysis. This is then followed by the presentation of the Minimum-Variance (thereafter, "MV") and the LPM algorithms that are used to solve the portfolio allocation problem. Finally, for this section, a description of the data used and the time period covered by the analysis will discussed. Section 4.3 presents and examines the portfolio results under the MV and the LPM approaches and Section 4.4 concludes this chapter.

In developing the relationship between LPM and Stochastic dominance, Bawa (1975) and Fishburn (1977) define an n-degree LPM as follows:

$$LPM_n = \int_{-\infty}^{h} (h - R_t)^n df(R_t) \qquad (4.4)$$

where h is the target rate of return, $f(R_t)$ is the probability of getting a return not exceeding h, R_t is the security returns and "n" is the power or exponential variable that determines the weights investors place on deviations. According to Nawrocki (1991), this yields the following computational formulae for LPM and CLPM (co-Lower Partial Moment). CLPM is similar to covariance used within a mean-variance framework. It estimates the interaction of LPM between two underlying assets held within a portfolio.

$$LPM_{in} = \frac{1}{k}\sum_{i=1}^{k} [Max\,(0, (h-R_{it})]^n, \qquad (4.5)$$

$$CLPM_{ij,\,n-1} = \frac{1}{k}\sum_{i=1}^{k} [Max\,(0, (h-R_{it})]^{n-1} (h-R_{jt}), \qquad (4.6)$$ [11]

where h is the target return, k is the number of observations, n is the LPM degree, which is non-negative and R_{it} is the periodic return for security i during time t while R_{jt} is the periodic return for security j during time t.

It is important that LPM is non-negative because LPM gives the magnitude of the risk measure and indicates the risk attitude of investors. This is reflected by the value of n, which it indicates how much protection the investor needs on the downside. More precisely, it measures or gives only an indication on the degree of skewness. Since investors prefer positive skewness rather than negative skewness, LPM becomes a measure of risk. Therefore, the higher the LPM value, the greater the degree of negative skewness and the greater the risk of the investment. While the lower the value of LPM, the more the investor is averse to the assets' below target returns' pattern. The analysis provides an evaluation of portfolios that are constructed on the basis of the two main types of risk measures. They are presented in the following section[12].

4.2.1 Portfolio Optimisation using the Minimum Variance Approach

The optimisation method for the Minimum Variance Approach is to:

$$\text{Minimize } Z_2 = \sum_{i=1}^{k}\sum_{j=1}^{k} x_i x_j \sigma_{ij} \tag{4.7}$$

Subject to:

$$\sum_{i=1}^{k} x_i \bar{R}_i = \bar{R}_p, \tag{4.8}$$

$$\sum_{i=1}^{k} x_i = 1, \qquad (4.9)^{13}$$

$$x_i \geq 0 \text{ for all } i, \tag{4.10}$$

where,

x_i	=	proportion of portfolio p invested in stock index of country *i*,
$\bar{R}_p$	=	The expected portfolio return,
$\bar{R}_i$	=	expected rate of return on the stock index of country *i*, and
σ_{ij}	=	The covariance between assets *i* returns and asset *j* returns.

[11] Equation (4.6) is substituted within Equation (4.11) later.

[12] The optimisations model to be presented in the next section is a simplification version of the model used in this chapter. The following optimisation assumes only a two-asset portfolio, while the empirical study of this chapter involved twelve assets making up of seven MSCI stock indexes assets and five Managed Futures assets. Microsoft EXCEL Solver is used to solve the optimisation problems that are listed in the following section.

[13] This constraint restricts any short selling of assets.

4.2.2 Portfolio Optimisation using The Lower Partial Moment approach

The following shows the downside risk approach developed from the equation that calculates the n-degree portfolio LPM. This was first found in Hogan and Warren (1972) and later applied in Nawrocki (1991).

$$LPM_{pn} = \sum_{i=1}^{k} \sum_{j=1}^{k} x_i x_j \, CLPM_{ij,\, n-1} \qquad (4.11)^{14}$$

where,

$$CLPM_{ij,\, n-1} = LPM_{jn}, \qquad when\ i = j, \qquad (4.12)$$

$$CLPM_{ij} \neq CLPM_{ji}, \qquad when\ i \neq j, \qquad (4.13)$$

And the objective function is to minimise the portfolio LPM, i.e,

$$\text{Minimise } Z_3 = \sum_{i=1}^{k} \sum_{j=1}^{k} x_i x_j \, CLPM_{ij,\, n-1}, \qquad (4.14)$$

Subject to constraint (4.8), (4.9) and (4.10)

As can be seen in (4.14), the minimisation function considers the co-Lower Partial Moment (CLPM). This implies that the LPM for the portfolio is minimised taking into account the interaction of the LPM of the underlying portfolio's assets, such that assets with the lowest interacted LPM value would only be considered for allocation within the portfolio[15].

[14] Apart from p, which is the notation for "portfolio", all other notations used in equation (4.11) to (4.14), such as, *k*, *i*, *j* and *n* follow that of equation (4.5) and (4.6).
[15] This way of modelling CLPM is also known as the Asymmetric CLPM, in which equation (4.6) is used to compute CLPM whereby $CLPM_{ij} \neq CLPM_{ji}$, *(when $i \neq j$)*, see Nawrocki (1991) for details.

The minimisation function used for the empirical analysis in this chapter also takes effect of the varying degree of skewness within the portfolio, whereby the value of "n" [in (4.5) and (4.6)] is adjusted from n=1 to n=4. This way of incorporating skewness within the LPM framework is discussed in Fishburn (1977) and applied in Nawrocki (1992).

4.2.3 Data and Time Periods

This empirical study uses monthly stock return data[16] for seven countries: the USA, Japan, West Germany, France, Switzerland, Canada and the UK. The data consists of the Morgan Stanley International stock indexes, which are accessible from DataStream International and are value weighted. The countries selected are the same as those in Eun & Resnick (1988). The reason is that it is in the currencies of these countries that the UK investors can hedge currency risk via a well-developed forward market. All the returns used for the empirical study are estimated using returns in terms of UK£, considering the one-month forward currency market.

Apart from the MSCI stock indexes, five Managed Futures Indexes were also considered in the UK investor portfolio. They are the Trend-Following CTA, Discretionary CTA, Diversified CTA, Currency CTA and the Financial CTA. The source of the data is from Managed Account Report, a company that specialises in studies of the alternative investment industry. The UK investors' portfolio of this empirical study consists of all Managed Futures and MSCI stock indexes as described.

[16] A summary of the Description of all the data used for Chapter 4, including the reasons for the use of the time period for this chapter, can all be found in table 3.2 of Chapter 3. Section 3.2.1.2 of the same chapter explains the choice and the selection of data used in this chapter, while Table 3.4(A) provides the summary of the descriptive statistics of these data for the entire sample period.

This empirical study analyses the portfolio performance effects for UK investors over the 9 years from 1990 to 1998. The length of the time series of sample observations (or the estimation interval) is from 1990 to 1993[17]. The out of sample periods is from 1994 to 1998. Holding-period-returns are then complied and used as a basis to compare portfolio performances. The reason to stop at 1998 is because France and Germany switched to the Euro from 1999 and, therefore, currency conversion becomes a problem. To avoid these added difficulties, we therefore only used the data up to 1998.

Table 4.2(A) presents summary statistics of the Managed Futures and the MSCI stock indexes for the in sample period from 1990 to 1993. Table 4.2(B) shows the summary statistics for the out sample period, 1994 to 1998. Table 4.2(A) shows (i.e., the in-sample summary statistics Table) that all of the Managed Futures indexes display significant positive skewness. The JB[18] statistics (that take into account both skewness and kurtosis) also reveal that in most cases (except for MSCI Switzerland stock index) the return distributions of the developed markets examined are not consistent with normality. Therefore, while the rationale behind the use of downside risk measures has been focused on Managed Futures, these descriptive statistics also show that, in the context of the data set under analysis, the same rationale could also be applied to the return distributions associated with most of these MSCI Developed Market stock indexes.

[17] The empirical research uses 1990 to 1993 (or 48 months) as in-sample periods because research findings have shown that using the 40-50 observations, for each asset underlying the portfolio, should be sufficient to estimate skewness that is to be used within a downside risk framework and therefore would tend to reduce estimation error. See, for example, Kroll & Levy (1980) for reference.

[18] JB statistics is Jarque Bera statistics, see Jarque & Bera (1987) for more information.

Table 4.2: Summary statistics of the 5 Managed Futures indexes and the 7 MSCI stock indexes used for the in sample period and out sample period

A) Summary statistics for the in sample period: 1990 to 1993

Managed Futures indexes	Mean	SD	Skew	LPM	Kurtosis	z-test
Currency	2.26%	5.61%	0.767	0.00048	0.411	*2.169
Diversified	1.42%	3.87%	0.534	0.00030	0.890	1.51
Finance	1.95%	4.71%	1.349	0.00033	4.556	***3.816
Discretion	2.12%	2.64%	0.285	0.00006	0.342	0.806
Trend	1.89%	6.01%	0.945	0.00065	1.735	***2.673

MSCI stock indexes	Mean	SD	Skew	LPM	Kurtosis	z-test
Canada	0.47%	3.40%	-0.040	0.00046	0.441	-0.113
France	0.70%	5.35%	-0.237	0.00121	0.108	-0.67
Japanese	-0.69%	7.77%	0.174	0.00321	0.276	0.492
Switzerland	1.45%	5.09%	-0.265	0.00088	1.665	-0.75
US	1.34%	3.72%	0.160	0.00037	1.505	0.453
UK	1.16%	4.77%	0.148	0.00071	-0.226	0.419
Germany	0.89%	6.03%	-0.640	0.00165	1.780	*-1.81

B) Summary statistics for the out sample period: 1994 to 1998

Managed Futures indexes	Mean	SD	Skew	LPM	Kurtosis	z-test
Currency	0.56%	2.48%	1.035	0.00015	3.049	***3.273
Diversified	0.97%	3.53%	0.440	0.00031	0.058	1.391
Finance	1.06%	3.53%	0.763	0.00025	0.453	*2.413
Discretion	0.73%	1.62%	0.335	0.00004	-0.240	1.059
Trend	0.95%	4.10%	0.651	0.00041	0.245	*2.059

MSCI stock indexes	Mean	SD	Skew	LPM	Kurtosis	z-test
Canada	1.25%	4.67%	-1.163	0.00092	4.488	***-3.678
France	1.53%	5.82%	-0.354	0.00124	-0.376	-1.119
Japanese	0.47%	5.24%	0.166	0.00111	0.202	0.525
Switzerland	2.14%	5.71%	-1.033	0.00127	1.864	***-3.267
US	1.92%	3.97%	-1.183	0.00055	2.901	***-3.741
UK	1.29%	3.85%	-0.499	0.00051	0.450	-1.578
Germany	1.74%	5.60%	-0.807	0.00128	1.606	*-2.552

Note:

The Skewness Z-statistics is estimated as $z = S/(6/N)^{0.5}$, while the Jarque-Bera Statistics tests for skewness by taking into taking into account kurtosis (the value left to the column of JB statistics as above). It is estimated as $JB = N[s^2/6 + (k-3)^2/24]$, where s denotes the value of skewness and k denotes the value of kurtosis, N denotes the number of data used for the test. The JB test follows a chi square distribution with 2 degree of freedom. * denotes 5% level significance (critical value for z-test is 1.96; critical value for chi square is 5.991), ** for 10% level significance (critical value for z-test is 1.65; critical value for chi square is 4.61) *** for 1% level significance (critical value for z-test is 2.58; critical value for chi square is 9.21).

4.3 Discussion of Results

Table 4.3 (following this page) presents the main empirical findings. Table 4.3(A) shows the asset allocations under LPM, that are of degree n=1 to n=4 (thereafter denoted as LPM1 to LPM4) and the underlying individual asset skewness statistics for the in sample period. Table 4.3(B) provides descriptive statistics for the portfolio returns for; both the in sample and out samples. This includes the monthly average returns, 4 years holding period returns (thereafter, as HPR) and the portfolio skewness for the MV, LPM1, LPM2, LPM3 and LPM4 approaches to asset allocations.

Table 4.3 shows that though LPM of the varying degree of n, might produce relatively better HPR in the out sample, this, however, is not the case for the MV approach. The MV approach produces relatively higher return of 87.52% for 4 years HPR in sample, but it only produces 77.13% in the out sample for 5 years HPR. This shows that the MV approach has not allocated assets and produce portfolio returns as good as it should be when the underlying assets exhibit significant skewness.

Moreover, it is also observed from Table 4.3(A) that the assets allocated fell from 12 to 3, when the allocation switches from using the MV approach to the LPM approach. Portfolio skewness is also observed to increase from 0.0671 to 0.1924 when switching from LPM1 to LPM4 for the in sample. And that skewness increases accordingly from 0.241 to 0.484 in the out sample. The MV approach, however, produces portfolio return that exhibits negative skewness – 0.15453 (for in sample) and

Table 4.3 : Portfolio allocations and in sample and out sample portfolio results of Minimum Variance and Minimum LPM using the Microsoft EXCEL software with 48 monthly returns (1990 to 1993) for 7 MSCI stock indexes and 5 Managed Futures indexes

A) Portfolio assets allocations

Portfolio Assets	Assets in-sample skewness	MV	LPM (n=1)	LPM (n=2)	LPM (n=3)	LPM (n=3)
MSCI Canada	-0.0399	19%	14%	28%	16%	17%
MSCI France	***-0.2375***	12%	0	0	0	0
MSCI Japan	***0.1745***	4%	0	0	0	0
MSCI Switzerland	***-0.2654***	2%	6%	0	0	0
MSCI US	***0.1599***	8%	7%	8%	18%	15%
MSCI UK	***0.1483***	4%	11%	10%	1%	0
MSCI Germany	***-0.6396***	2%	0	0	0	0
Currency CTA	***0.7672***	2%	0	0	0	0
Diversified CTA	***0.5337***	4%	45%	17%	64%	67%
Finance CTA	***1.3494***	3%	14%	37%	1%	0
Discretionary CTA	***0.2847***	32%	3%	0	0	0
Trend Following CTA	***0.9450***	9%	0	0	0	0
Total allocation		**100**	**100**	**100**	**100**	**100**
Number of assets allocated		**12**	**7**	**5**	**5**	**3**

B) Portfolio statistics

In-sample results	**MV**	**LPM 1**	**LPM 2**	**LPM 3**	**LPM 4**
Average monthly returns	1.34%	1.35%	1.32%	1.26%	1.25%
4 years (1990 to 1993) holding periods returns	87.52%	87.72%	84.57%	78.92%	78.12%
Standard Deviation	2.09%	2.64%	2.74%	2.70%	2.78%
Skewness	***-0.15453***	***0.0671***	***0.0856***	***0.1308***	***0.1924***

Out-sample results	**MV**	**LPM 1**	**LPM 2**	**LPM 3**	**LPM 4**
Average monthly returns	0.98%	1.09%	1.08%	1.01%	1.01%
5 years (1994 to 1998) holding periods returns	77.13%	89.03%	87.78%	80.25%	79.28%
Standard Deviation	2.14%	2.13%	2.08%	2.37%	2.43%
Skewness	***-0.31444***	***0.2410***	***0.3403***	***0.4262***	***0.4804***

Note:

1) The critical values for testing the differences of the portfolio returns among the various allocation methods (i.e., LPM of n=1, n=2, n=3, n=4 and the MV) are 2.43 (5% significant level), 3.45 (1% significant level). As the F critical value (p value) is about 2.40 (0.9986), the null hypothesis of no difference among the monthly returns series generated by the various allocation methods cannot be rejected. These portfolios returns are therefore not significantly different from one another. Our results are similar to that in Nawrocki (1992), which also show that portfolio out sample returns decrease from 2.514 to 2.4849 as the LPM is adjusted from n=1 to n=4. Nawrocki (1992), however, does not provide any statistical information to show whether the results are significantly different from one another. 2) The value of skewness in italics and bold indicates normality can be rejected at 5% based on z-test.

–0.3144 (for out sample). The findings shown in Table 4.3(A) are similar to Nawrocki (1992) and in support of Simkowitz & Beedles (1978)[19].

Given that the correlation coefficient underlying two assets would affect the portfolio returns, within a framework where the portfolio uses the MV approach, the same would therefore be applied to the correlation of the assets' LPM for portfolio allocation that consider the minimum portfolio LPM approach. Correlation of assets' LPM, however, only captured correlation of below target returns of assets. The upside returns correlation will not be captured because they are not within the LPM's computation[20]. The following will discuss the effect of correlation of the underlying assets' return on the portfolio by first looking at the allocated assets within the portfolio.

Three of the main assets allocated using the MV approach, as shown in Table 4.3(A), the Discretionary CTA, MSCI Canada and MSCI France stock indexes have relatively higher proportion. Table 4.4 following this page shows that the in sample correlation for Discretionary CTA with MSCI Canada stock index and MSCI France stock index are -0.125 and -0.291 respectively. Low or even negative correlation coefficient between two underlying assets is essential when the objective function is to minimise the portfolio variance. However, when the underlying assets are significantly skewed, i.e., when the distributional returns follow an asymmetric pattern, correlation might not be captured or reflected with respect to the upside or downside returns as

[19] Simkowitz & Beedles (1978) argue that if positive skewness is a desirable characteristic of return distributions, then the fact that the simple act of diversification destroys skew is a likely explanation of observed behaviour. Moreover, they also produce results to support the fact that, even if in perfect, frictionless markets, there would still be investors that would hold a limited number of assets in their portfolios, the exact number being a function of each individual's skewness/variance awareness. Those who are most concerned with skew (dispersion) should hold a relatively small (large) number of assets in their portfolios.

[20] See Appendix 4.1 that shows the computation of data series for LPM of assets' returns.

Table 4.4: Correlation coefficient of returns of the 5 MSCI stock indexes and 7 Managed Futures indexes used for the in sample (1990 to 1993), out sample (1994 to 1998) and for the full period (1990 to 1998)

1) Correlation coefficient for the underlying indexes for the in sample period - 1990 to 1993

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	*** 0.382										
Japan	*** 0.42	*** 0.39									
Swiss	*** 0.632	*** 0.671	*** 0.466								
USA	*** 0.637	*** 0.515	* 0.305	*** 0.635							
UK	*** 0.542	*** 0.682	* 0.37	*** 0.767	*** 0.659						
Germany	*** 0.435	*** 0.735	* 0.302	*** 0.603	*** 0.4	*** 0.579					
Finance	-0.07	-0.165	-0.128	-0.041	-0.093	-0.117	-0.087				
Diversified	0.048	-0.2	-0.173	-0.081	-0.139	-0.182	0.095	*** 0.729			
finance	0.057	-0.174	-0.117	-0.042	-0.141	-0.148	0.101	*** 0.712	*** 0.9		
discretion	-0.125	*-0.291	-0.239	-0.144	-0.093	-0.219	-0.205	*** 0.467	*** 0.58	*** 0.48	
trend	0.056	-0.146	-0.129	-0.016	-0.111	-0.138	0.122	*** 0.809	*** 0.95	*** 0.948	*** 0.528

2) Correlation coefficient for the underlying indexes for the out sample period - 1994 to 1998

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	*** 0.606										
Japan	*** 0.358	*** 0.448									
Swiss	*** 0.595	*** 0.739	*** 0.493								
USA	*** 0.801	*** 0.589	*** 0.424	*** 0.61							
UK	*** 0.691	*** 0.743	*** 0.425	*** 0.65	*** 0.631						
Germany	*** 0.552	*** 0.778	*** 0.414	*** 0.714	*** 0.598	*** 0.655					
Finance	-0.013	-0.127	-0.132	-0.048	0.095	-0.196	-0.113				
Diversified	*-0.266	-0.135	-0.073	-0.026	-0.108	-0.2	-0.197	*** 0.395			
finance	*-0.262	-0.212	-0.105	-0.141	-0.166	*-0.283	*-0.27	*** 0.577	*** 0.763		
discretion	-0.074	0.067	-0.02	0.109	0.02	-0.041	0.051	*** 0.368	*** 0.595	*** 0.472	
trend	* -0.268	-0.189	-0.115	-0.1	-0.114	* -0.259	** -0.243	*** 0.596	*** 0.912	*** 0.923	*** 0.494

3) Correlation coefficient for the underlying indexes for the full period - 1990 to 1998

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.528										
Japan	***0.369	***0.41									
Swiss	***0.607	***0.713	***0.467								
USA	***0.739	***0.561	***0.357	***0.622							
UK	***0.607	***0.705	***0.39	***0.695	***0.637						
Germany	***0.501	***0.758	***0.351	***0.665	***0.512	***0.614					
Finance	-0.057	-0.149	-0.142	-0.051	-0.036	-0.136	-0.103				
Diversified	-0.146	-0.168	-0.133	-0.054	-0.125	-0.191	-0.06	***0.582			
finance	-0.126	-0.196	-0.121	-0.097	-0.158	-0.206	-0.079	***0.658	***0.833		
discretion	-0.116	-0.139	-0.183	-0.044	-0.062	-0.146	-0.114	***0.469	***0.564	***0.482	
trend	-0.12	-0.168	-0.131	-0.061	-0.116	-0.187	-0.046	***0.737	***0.924	***0.938	***0.517

Note:
* is Pearson correlation coefficient significant at 5% level, ** at 10% level and *** at 1% level significance. Critical values for 5%, 1% and 10% differ across the three time periods in which the correlations are computed. For the in sample period 1990 to 1993 critical values for 5% = 0.284, 1% = 0.368 and 10% = 0.2406. For the out sample period 1994 to 1998, critical values for 5% = 0.254, 1% = 0.33 and 10% = 0.1194. For the full period 1990 to 1998, critical values for 5% = 0.187, 1% = 0.248 and 10% = 0.1155

much as it should be[21] This naturally makes the MV approach an imperfect choice of solution to the asset allocation problem which explains why, when compared with the MV approach, the LPM approaches (for LPM1 to LPM4) are capable of producing much higher portfolio HPR in the out sample.

As explained earlier, the LPM provides information on the correlation of below target returns of the underlying assets and that it will tend to capture the correlation of returns more accurately if these asset returns are significantly skewed. The empirical analysis will now proceed to discuss how the correlations of assets' returns modelled within LPM1 to LPM4 for the optimisation framework might have a potential impact on the portfolio HPR of the out sample. The discussions will be based largely on the correlation of returns of LPM1 to LPM4 of the various assets in-sample (i.e., Table 4.5) to explain how these assets are being allocated using these LPM approaches. Table 4.5, 4.6 and 4.7 in the following pages show the correlations of returns of LPM1 to LPM4 of the various assets for the in sample (Table 4.5), out sample (Table 4.6) and full periods (Table 4.7) respectively.

Table 4.3(A) shows the assets allocated under portfolio of LPM1 are: the Discretionary CTA, the Diversified CTA, the Finance CTA, the MSCI Canada, MSCI US, and MSCI UK Indexes. Portfolio skewness is largely contributed by the high correlation of LPM1 of the underlying assets. Allocating proportion of portfolio to assets that have highly correlated LPM1 allows portfolio to place more weighting on assets that tend to generate above target returns. This eventually contributes to overall portfolio skewness and portfolio returns. For example, Table 4.5 shows correlation of returns of LPM1 between Diversified CTA and Finance CTA is a significant huge 0.813. This will therefore contribute to increasing portfolio return more reliably.

[21] See, for e.g., Rey (2000).

Table 4.5: Correlation coefficient of returns of Lower Partial Moment (for degree n=1 to n=4) for the 5 MSCI stock indexes and 7 Managed Futures indexes used for the in sample period (1990 to 1993)

1) Correlation coefficient of Lower Partial Moment of degree n=1 for the underlying indexes (LPM1)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.411										
Japan	*0.299	***0.525									
Swiss	***0.561	***0.809	***0.557								
USA	***0.644	***0.771	***0.449	***0.825							
UK	***0.573	***0.767	***0.488	***0.758	***0.689						
Germany	***0.505	***0.772	***0.431	***0.89	***0.651	***0.752					
Finance	-0.075	-0.143	-0.141	-0.143	-0.086	-0.192	-0.107				
Diversified	0.092	-0.14	-0.135	-0.013	0.061	0.016	0.048	***0.43			
finance	0.29	-0.161	-0.106	0.031	0.047	0.074	0.077	***0.456	***0.813		
discretion	-0.045	0.047	-0.085	-0.074	-0.014	-0.046	0.026	*0.35	**0.257	**0.253	
trend	0.164	-0.134	-0.162	-0.017	0.011	0.015	0.065	***0.628	***0.857	***0.895	***0.427

2) Correlation coefficient of Lower Partial Moment of degree n=2 for the underlying indexes (LPM2)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	*0.317										
Japan	0.158	***0.541									
Swiss	*0.359	***0.944	***0.584								
USA	***0.454	***0.845	*0.307	***0.809							
UK	***0.493	***0.754	***0.551	***0.698	***0.536						
Germany	*0.364	***0.889	***0.644	***0.941	***0.63	***0.744					
Finance	-0.109	-0.098	-0.099	-0.091	-0.068	-0.146	-0.093				
Diversified	0.148	-0.089	-0.108	-0.044	-0.019	0.009	-0.026	***0.574			
finance	0.261	-0.103	-0.1	-0.037	-0.049	0.046	-0.023	***0.612	***0.908		
discretion	-0.07	0	-0.078	-0.051	-0.028	-0.077	-0.031	***0.361	0.072	0.036	
trend	0.185	-0.092	-0.12	-0.056	-0.053	0.009	-0.03	***0.727	***0.894	***0.919	*0.371

3) Correlation coefficient of Lower Partial Moment of degree n=3 for the underlying indexes (LPM3)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	0.191										
Japan	0.074	***0.484									
Swiss	0.2	***0.981	***0.548								
USA	*0.29	***0.877	0.176	***0.828							
UK	***0.378	***0.703	***0.588	***0.684	***0.449						
Germany	0.212	***0.86	***0.738	***0.908	***0.563	***0.757					
Finance	-0.09	-0.075	-0.081	-0.069	-0.058	-0.117	-0.073				
Diversified	0.13	-0.065	-0.08	-0.05	-0.039	-0.018	-0.045	***0.697			
finance	0.194	-0.063	-0.071	-0.043	-0.047	0.009	-0.037	***0.739	*** 0.940		
discretion	-0.055	-0.025	-0.058	-0.04	-0.032	-0.067	-0.037	*0.309	-0.001	-0.016	
trend	0.156	-0.066	-0.085	-0.053	-0.052	-0.015	-0.046	***0.812	***0.915	***0.946	*0.292

4) Correlation coefficient of Lower Partial Moment of degree n=4 for the underlying indexes (LPM4)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	0.101										
Japan	0.027	***0.409									
Swiss	0.103	***0.99	***0.497								
USA	0.172	***0.907	0.09	***0.856							
UK	**0.281	***0.646	***0.63	***0.668	***0.395						
Germany	0.107	***0.787	***0.797	***0.853	***0.49	***0.779					
Finance	-0.07	-0.06	-0.067	-0.057	-0.049	-0.095	-0.059				
Diversified	0.092	-0.05	-0.061	-0.046	-0.039	-0.035	-0.045	***0.791			
finance	0.132	-0.044	-0.052	-0.038	-0.037	-0.015	-0.036	***0.827	***0.96		
discretion	-0.042	-0.03	-0.045	-0.034	-0.03	-0.057	-0.034	**0.247	-0.023	-0.025	
trend	0.113	-0.05	-0.062	-0.046	-0.042	-0.03	-0.044	***0.87	***0.941	***0.97	0.214

Note: * is Pearson correlation coefficient significant at 5% level, ** at 10% level and *** at 1% level significance. For the in sample period 1990 to 1993, in which the correlation is computed, critical values for 5% = 0.284, 1% = 0.368 and 10% = 0.2406.

Table 4.6: Correlation coefficient of returns of Lower Partial Moment (for degree n=1 to n=4) for the 5 MSCI stock indexes and 7 Managed Futures indexes used for the out sample period (1994 to 1998)

1) Correlation coefficient of Lower Partial Moment of degree n=1 for the underlying indexes (LPM1)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.523										
Japan	***0.533	***0.635									
Swiss	***0.684	***0.803	***0.645								
USA	***0.867	***0.628	***0.628	***0.753							
UK	***0.549	***0.786	***0.569	***0.651	***0.622						
Germany	***0.64	***0.796	***0.634	***0.835	***0.701	***0.72					
Finance	-0.009	-0.047	-0.169	-0.094	0.001	-0.023	-0.18				
Diversified	-0.148	-0.023	-0.171	-0.11	-0.127	-0.122	-0.159	***0.349			
finance	-0.063	-0.205	-0.228	-0.177	-0.074	**-0.228	**-0.221	***0.42	***0.637		
discretion	-0.013	-0.021	-0.099	-0.012	-0.003	-0.068	-0.001	***0.374	***0.497	***0.376	
trend	-0.056	-0.111	**-0.22	-0.171	-0.06	-0.172	**-0.22	***0.503	***0.863	***0.846	***0.43

2) Correlation coefficient of Lower Partial Moment of degree n=2 for the underlying indexes (LPM2)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.598										
Japan	***0.78	***0.741									
Swiss	***0.85	***0.821	***0.787								
USA	***0.975	***0.643	***0.815	***0.879							
UK	***0.689	***0.774	***0.751	***0.659	***0.716						
Germany	***0.845	***0.798	***0.827	***0.882	***0.88	***0.767					
Finance	-0.034	-0.017	-0.103	-0.103	-0.027	0.069	-0.132				
Diversified	-0.079	-0.089	-0.139	-0.088	-0.086	-0.116	-0.119	**0.248			
finance	-0.06	-0.16	-0.16	-0.119	-0.072	-0.151	-0.138	**0.232	***0.709		
discretion	-0.041	-0.072	-0.078	-0.046	-0.04	-0.071	-0.041	**0.249	**0.32	0.095	
trend	-0.059	-0.125	-0.174	-0.122	-0.075	-0.135	-0.143	***0.381	***0.881	***0.857	0.192

3) Correlation coefficient of Lower Partial Moment of degree n=3 for the underlying indexes (LPM3)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.664										
Japan	***0.905	***0.769									
Swiss	***0.93	***0.836	***0.886								
USA	***0.996	***0.681	***0.915	***0.94							
UK	***0.799	***0.769	***0.86	***0.757	***0.806						
Germany	***0.935	***0.784	***0.924	***0.937	***0.951	***0.829					
Finance	-0.042	-0.024	-0.068	-0.08	-0.039	0.096	-0.088				
Diversified	-0.051	-0.093	-0.093	-0.066	-0.055	-0.091	-0.078	0.145			
finance	-0.05	-0.12	-0.102	-0.079	-0.056	-0.105	-0.086	0.118	0.806		
discretion	-0.025	-0.055	-0.047	-0.034	-0.026	-0.047	-0.034	0.188	0.195	0.002	
trend	-0.048	-0.105	-0.106	-0.078	-0.055	-0.097	-0.085	**0.254	0.908	0.885	0.067

4) Correlation coefficient of Lower Partial Moment of degree n=4 for the underlying indexes (LPM4)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.722										
Japan	***0.958	***0.785									
Swiss	***0.969	***0.845	***0.942								
USA	***0.999	***0.728	***0.961	***0.972							
UK	***0.875	***0.78	***0.921	***0.848	***0.876						
Germany	***0.973	***0.786	***0.965	***0.969	***0.978	***0.885					
Finance	-0.041	-0.036	-0.052	-0.061	-0.04	0.091	-0.063				
Diversified	-0.04	-0.08	-0.063	-0.051	-0.041	-0.07	-0.054	0.077			
finance	-0.042	-0.093	-0.069	-0.058	-0.044	-0.078	-0.06	0.053	***0.869		
discretion	-0.02	-0.043	-0.032	-0.026	-0.02	-0.035	-0.026	0.142	0.115	-0.024	
trend	-0.038	-0.081	-0.065	-0.053	-0.041	-0.07	-0.055	0.157	***0.936	***0.896	0.013

Note: * is Pearson correlation coefficient significant at 5% level , ** at 10% level and *** at 1% level significance. For the in sample period 1990 to 1993, in which the correlation is computed, critical values for 5% = 0.254, 1% = 0.33 and 10% = 0.1194.

Table 4.7: Correlation coefficient of returns of Lower Partial Moment (for degree n=1 to n=4) for the 5 MSCI stock indexes and 7 Managed Futures indexes used for the full sample period (1990 to 1998)

1) Correlation coefficient of Lower Partial Moment of degree n=1 for the underlying indexes (LPM1)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.477										
Japan	***0.37	***0.548									
Swiss	***0.644	***0.802	***0.548								
USA	***0.797	***0.68	***0.491	***0.778							
UK	***0.536	***0.774	***0.518	***0.682	***0.638						
Germany	***0.57	***0.783	***0.502	***0.846	***0.67	***0.736					
Finance	-0.041	-0.093	-0.12	-0.114	-0.044	-0.109	-0.123				
Diversified	-0.059	-0.076	-0.152	-0.069	-0.051	-0.06	-0.061	***0.374			
finance	0.074	-0.183	-0.151	-0.083	-0.02	-0.074	-0.067	***0.429	***0.723		
discretion	-0.023	0.011	-0.095	-0.039	-0.007	-0.06	0.012	***0.345	***0.373	***0.309	
trend	0.032	-0.119	**-0.169	-0.099	-0.028	-0.067	-0.065	***0.578	***0.851	***0.871	***0.426

2) Correlation coefficient of Lower Partial Moment of degree n=2 for the underlying indexes (LPM2)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.473										
Japan	***0.303	***0.536									
Swiss	***0.749	***0.847	***0.517								
USA	***0.909	***0.663	***0.383	***0.857							
UK	***0.571	***0.763	***0.552	***0.657	***0.63						
Germany	***0.589	***0.839	***0.653	***0.857	***0.711	***0.747					
Finance	-0.045	-0.067	-0.055	-0.079	-0.041	-0.063	-0.084				
Diversified	-0.026	-0.089	-0.108	-0.067	-0.058	-0.053	-0.066	***0.448			
finance	0.018	-0.12	-0.099	-0.07	-0.052	-0.028	-0.058	***0.538	***0.822		
discretion	-0.038	-0.03	-0.066	-0.046	-0.032	-0.069	-0.033	***0.327	**0.165	0.055	
trend	0.003	-0.099	-0.107	-0.08	-0.055	-0.038	-0.061	***0.665	***0.863	***0.903	***0.322

3) Correlation coefficient of Lower Partial Moment of degree n=3 for the underlying indexes (LPM3)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.458										
Japan	*0.224	***0.472									
Swiss	***0.842	***0.822	***0.422								
USA	***0.965	***0.609	***0.26	***0.911							
UK	***0.648	***0.727	***0.521	***0.719	***0.686						
Germany	***0.576	***0.825	***0.708	***0.823	***0.67	***0.766					
Finance	-0.029	-0.057	-0.04	-0.05	-0.031	-0.051	-0.054				
Diversified	-0.023	-0.076	-0.07	-0.054	-0.041	-0.051	-0.056	***0.563			
finance	-0.007	-0.07	-0.057	-0.045	-0.034	-0.019	-0.041	***0.697	***0.871		
discretion	-0.022	-0.035	-0.042	-0.034	-0.024	-0.052	-0.033	***0.284	0.059	-0.007	
trend	-0.012	-0.069	-0.063	-0.051	-0.037	-0.03	-0.046	***0.773	***0.872	***0.94	***0.254

4) Correlation coefficient of Lower Partial Moment of degree n=4 for the underlying indexes (LPM4)

	Canada	France	Japan	Swiss	USA	UK	Germany	Currency	Diversified	finance	discretion
France	***0.447										
Japan	0.159	***0.401									
Swiss	***0.91	***0.757	***0.315								
USA	***0.987	***0.557	**0.173	***0.948							
UK	***0.735	***0.681	***0.473	***0.791	***0.757						
Germany	***0.57	***0.785	***0.734	***0.769	***0.628	***0.78					
Finance	-0.021	-0.046	-0.032	-0.034	-0.023	-0.044	-0.039				
Diversified	-0.022	-0.059	-0.048	-0.041	-0.029	-0.046	-0.045	***0.675			
finance	-0.012	-0.044	-0.035	-0.03	-0.021	-0.02	-0.03	***0.809	0.894		
discretion	-0.016	-0.032	-0.03	-0.025	-0.018	-0.04	-0.028	*0.233	0.012	-0.017	
trend	-0.015	-0.048	-0.039	-0.034	-0.024	-0.028	-0.035	***0.85	0.892	0.966	0.195

Note: * is Pearson correlation coefficient significant at 5% level, ** at 10% level and *** at 1% level significance. For the in sample period 1990 to 1993, in which the correlation is computed, critical values for 5% = 0.187, 1% = 0.248 and 10% = 0.1155.

The high correlation of returns of LPM1 of Diversified CTA and Finance CTA would mean that the below target variations are more correlated. On the other hand, this means that the two CTAs are more likely to produce above target returns together (quite often). And naturally, the negative effect of the highly correlated returns of LPM1 (i.e., cases when both CTAs returns fall below target returns) between finance CTA and diversified CTA are curbed by the other allocated assets. This is being minimised by the low correlation of returns of LPM1 of Diversified CTA with MSCI Canada (0.092), with MSCI Switzerland (-0.013), with MSCI US (0.061) and MSCI UK (0.016) stock indexes. It is also minimised by the low correlation of LPM1 of Finance CTA with MSCI Canada (0.29), with MSCI Switzerland (0.031), with MSCI UK (0.047) and with MSCI UK (0.074). Together these allocated assets help to achieve the objective function of a Minimum LPM (downside risk) portfolio.

The number of assets allocated fell to 5 when using portfolio of LPM2, with only assets allocated to the Diversified CTA, the Finance CTA, MSCI Canada, MSCI US and MSCI UK stock indexes. The correlation of returns of LPM2 of Finance CTA and Diversified CTA remains at a significantly huge 0.908 as seen from Table 4.5. However, as the number of assets that the portfolio allocated has reduced from 7 to 5, this also reduces the power of diversification for the underlying assets. Therefore, it produces a relatively lower out sample 5 years HPR of only 87.78% (compared with portfolio HPR of 89.03% when assets are allocated within portfolio of LPM1). However, portfolio skewness increases to 0.3403 (compared with portfolio skewness of 0.241 when assets are allocated within portfolio of LPM1).

For the assets allocated under portfolio of LPM3, the assets allocated are the same as the portfolio of LPM2. However, the proportions change. Table 4.3 shows that the allocation for MSCI UK stock index and Finance CTA reduced to only 1% and this reduces the power of diversification to quite a large extent and consequently increases the portfolio skewness to 0.4262 (when compared with portfolio skewness when assets are allocated under LPM2)[22]. The 5 years HPR is reduced to only 80% for the out sample, when compared with the HPR when the assets are allocated within portfolio of LPM2.

The number of assets allocated under portfolio of LPM4 reduced further to 3, but there are not many changes in the proportions of assets held within the portfolio. The 3 assets held are, firstly MSCI Canada stock index, which increases from 16% (portfolio of LPM3) to 17% (portfolio of LPM4). Secondly, MSCI US stock index, which reduces from 18% (portfolio of LPM3) to 15% (portfolio of LPM4). And lastly, Diversified CTA, which increases from 64% (portfolio of LPM3) to 67% (portfolio of LPM4).

Table 4.5 shows that correlation of returns of LPM4 for diversified CTA and MSCI Canada stock index is 0.092; while that of diversified CTA and MSCI US stock index is –0.039, and that of MSCI Canada stock index and MSCI US stock index is 0.172. The low correlation of returns of LPM4 of these assets might be good for diversifying unnecessary losses away, but it does not guarantee that they are good quality assets to help portfolio capture and maintain strong upside, above the target returns. This is because as explained earlier, the correlations of upside returns using the LPM approach are not captured because they are not within the scope for LPM's computation. Nevertheless, this increases the portfolio skewness to 0.4804 (when

[22] See footnote 19.

compared with the portfolio skewness when the assets are allocated under LPM3), given that the underlying assets are also significantly skewed (except for MSCI Canada stock index). The out sample HPR has continued to reduce to 79.28% when compared with the HPR when assets are allocated within portfolio of LPM3.

4.4 Concluding Remarks

Since the publication of the seminal work of Markowitz (1959), numerous subsequent studies on portfolio selection and performance measures have been published and the vast majority of these analyses have been based on the first two moments of return distributions. Markowitz (1959), however, also discussed the case of risk as variability (variance) below the target level of mean. He defined the measure of variance of this nature as semi-variance. Markowitz (1959) explains the complexity (in the 1950's) associated with the practical implementation of the computational algorithm of semi-variance, e.g., the cost, convenience, familiarity, and the desirability of the portfolios produced by the analysis. Analysing risk in term of variance, in these circumstances naturally turned out to be preferred (superior) over the alternative of analysing risk in terms of semi-variance (see (4.1) for the semi-variance algorithm). Even so, Markowitz (1959) suggested that these computational difficulties should not prevent the use of semi-variance. Indeed, Harlow (1991) and Nawrocki (1999), amongst many others, are two examples of studies that acknowledge the limitation of addressing the issue of downside risk in Markowitz (1959), and go on to conduct portfolio analysis based on using below target return variation as a risk measure.

Fishburn (1977) follows up the issue of semi-variance discussed by Markowitz (1959) and argues that adjusting the power of the semi-variance or below target variance (Equation 4.1), would help approximate a wide variety of attitudes towards risk of falling below a certain target level of returns. Adjustment of the value of "n" (equation 4.3) could therefore often reflect the risk appetite of investors.

In this chapter, the empirical study tested the effectiveness of the downside risk approach to the asset allocation process when Managed Futures and the various MSCI stock indexes are included within the same portfolio. Following Nawrocki (1992), the study undertook empirical tests using the Lower Partial Moment framework, in which the value of "n" (of 4.3) is adjusted to account for the different level of skewness within the portfolio, where the appetite for risk differs. The results were then compared with that of the Minimum Variance approach.

The out sample results showed that as the value of "n" increases, the level of skewness rises and Holding Period Returns fall. Moreover, it was observed that comparatively, the Minimum Variance approach did not produce relatively higher out sample Holding Period Returns than the Lower Partial Moment approaches. This shows that when the assets within the portfolio exhibit strong skewness, the Minimum Variance approach might not be as good a choice for asset allocation as it otherwise might be.

Furthermore, it was also observed that when switching from using the Minimum Variance to the Lower Partial Moment approach, the number of assets allocated falls from 12 to as few as 3. This is to be expected, and consistent with much of the existing literature, e.g., Nawrock (1999) and Simkowitz & Beedles (1978), regarding the negative effect of portfolio skewness on diversification that could result in portfolios being allocated with relatively fewer assets.

The findings in this chapter show that using Managed Futures and equity assets within the same portfolio could have potential benefits to UK investors if the allocation process takes into account the presence of the significant skewness underlying the assets being considered for inclusion in the portfolio. The Lower Partial Moment approach was used in the allocation process and it was found that increasing skewness weakened the power of diversification. Even though this finding on the relationship between skewness and diversification is consistent with previous academic studies, using the Lower Partial Moment approach did however show that adjusting for skewness in the allocation process could also affect portfolio returns. Skewness, after all, is not as undesirable as it might appear to be as described in Simkowitz & Beedles (1978). This means that, by adjusting skewness to desirable levels, it may still possible to allow the allocation process to allocate assets that would help attain the best possible portfolio returns. Indeed, as was demonstrated earlier, the out sample Holding Period Returns can often be relatively better when compared with the Minimum Variance approach to portfolio allocation.

Appendix 4.1: Illustration of Lower Partial Moment

Lower Partial Moment (LPM) = $\frac{1}{K}\sum_{i=1}^{k}[\text{Max}(0, (t-R_T)]^2$

where R_T is the asset return during time period T, K is the number of observations, t is the target rate of return

Assuming that the target rate of return is zero, and using the LPM formula above, we compute the value of LPM (n=2) for the following two assets

	Asset A	LPM	Asset B	LPM
Period 1	**0.15**	**0**	**0.15**	**0**
Period 2	**-0.56**	**0.3136**	**0.56**	**0**
Period 3	**0.06**	**0**	**0.06**	**0**
Period 4	**0**	**0**	**0**	**0**
Period 5	**-0.6**	**0.36**	**0.6**	**0**
Period 6	**0.04**	**0**	**0.04**	**0**
Period 7	**-0.04**	**0.0016**	**0.04**	**0**
Period 8	**-0.7**	**0.49**	**0.7**	**0**
Period 9	**0.55**	**0**	**0.55**	**0**
Period 10	**-0.85**	**0.7225**	**0.85**	**0**
	LPM-A	**0.18877**	**LPM-B**	**0**

Notes:

1) LPM for B is zero because LPM for B does not capture any returns above the target level.

2) LPM-A of 0.18877 is the average variation of return below target level for asset A for the 10 periods.

3) The smaller the value of LPM, the larger the frequency of returns to be fluctuating above target returns for the full periods.

Appendix 4.2: Proof of the sufficiency of the Stochastic Dominance Theorems[1]

(From Elton & Gruber, 1991)

Theorem 1 First Order Stochastic Dominance. F Dominates G if:

1. The investor prefers more to less $U'(X) > 0$, and

2. $F(X) \leq G(X)$ for all X and $F(X) < G(X)$ for at least one value, where $F(X)$ and $G(X)$ are cumulative probability distribution (i.e., the cumulative probability is the likelihood of obtaining a given return or less) functions of F and G, respectively.

Proof F is preferred to G if the expected utility of distribution F is greater than the expected utility of G. The expected utility of

$$F = \int_a^b U(X)dF(X)$$

And the expected utility of

$$G = \int_a^b U(X)dG(X)$$

[1]This appendix only serves to give some elementary knowledge, showing how investor's preference can be dealt with within a stochastic dominance framework, when the expected utility function is taken into account The mathematical proof shown in this appendix is extracted from Gruber (1991), pg 236 to 238. It is a summarised version of a more elaborate proof found in Bawa (1975), in which consideration for sufficiency as well as necessity are taken into account when writing the proof.

a and b are simply the smallest and the largest values of F and G can take on. Thus, for F to be preferred to G,

$$\int_a^b U(X)dF(X) > \int_a^b U(X)dG(X)$$

Or

$$\int_a^b U(X)dF(X) - \int_a^b U(X)dG(X) > 0$$

Recall $\int_a^b udw = uw]_a^b - \int_a^b wdu$ as the basis for integration by parts, and by defining u as $U(x)$ and dw as $d[F(X) - G(X)]$, solving them (using integration by parts) yields the following:

$$\int_a^b U(X)d[F(x) - G(x)] = U(x)[F(x) - G(x)]_a^b - \int_a^b U'(X)[F(x) - G(x)]dx$$

$F(b)=G(b)=1$ and $F(a)=G(a)=1$ by definition. Thus, F dominates G if the last term is positive (i.e., the integral negative). By assumption, $U'(X)$ is positive. The integral adds up values of $U'(x)$ and $F(x) - G(x)$. For this integral to be negative, no matter what patter $U'(x)$ takes on (and, thus for the last term to be positive), $F(x)$ must be less than or equal to $G(x)$ for all x. For it to have a value different from zero, the strict inequality must hold for some value. This completes the proof.

Theorem 2 Second-order stochastic dominance. *F* is preferred to *G* if:

1. Investors prefer more to less $U'(x) > 0$,

2. Investors are risk averse $U''(x) < 0$, and

3. $\int_a^x F(y)dy \leq \int_a^x G(y)dy$

   For all x with the strict inequality holding for some value

F is preferred to G if the expected utility of F is greater than the expected utility of G. In the last section we showed this is equivalent to

$$-\int_a^b U'(X)[F(x)-G(x)]dx < 0$$

Integrating once more by parts yields

$$-U'(x)\int_a^x [F(y)-G(y)]dy]_a^b + \int_a^b U''(x)\int_a^x [F(y)-G(y)]dydx$$

Or

$$-U'(b)\int_a^b [F(y)-G(y)]dy + \int_a^b U''(x)\int_a^x [F(y)-G(y)]dydx$$

$U'(b)>0$ by definition. Therefore, the first term is positive if the integral is negative. $U''(x)<0$ by definition. Thus the second term is positive if the integral is negative or zero for all values of X. For the terms to be nonzero, the integral must be strictly negative for at least one value of X. The theorem is proven.

Theorem 3 **Third order stochastic dominance** is F dominates G if:

1. Investors prefer more to less $U'(x) > 0$,

2. Investors are risk averse $U''(x) < 0$,

3. The third derivative of the utility function is positive $U'''(x)>0$,

4. The mean of F is greater than the mean of G, and

5. $\int_a^x \int_a^t [F(y) - G(y)]dydt \leq 0$ for all x and the strict inequality holds for some value, where t lies between a and b.

Proof F dominates G if the expected utility of F is greater than the expected utility of G. In the last section this required that

$$-U'(b)\int_a^b [F(y) - G(y)]dy + \int_a^b U''(x)\int_a^x [F(y) - G(y)]dydx > 0$$

Integrating the second term by parts yields

$$-U'(b)\int_a^b [F(y)-G(y)]dy + U''(b)\int_a^t \int_a^b [F(y)-G(y)]dydt$$

$$-\int_a^b U'''(x)\int_a^x \int_a^t [F(y)-G(y)]dydxdt$$

Note that

$$\int_a^b [F(y)-G(y)]dy$$

is the difference in means between G and F. Since, by assumption, the mean of G is less than the mean of F, this is negative. U' (x)>0 by assumption; thus the first term is positive. Similarly, U'' (x) < 0 and U''' > 0; thus the last two terms are positive if the double integral is negative. This completes the proof.

Appendix 4.3: Summarised derivation for the Arrow-Pratt coefficient of absolute risk aversion (Adapted from Elton & Gruber, 1991), page 206-209)

The definition of Decreasing Absolute Risk Aversion (DARA) is that as wealth increases for an investor, he becomes less risk averse and holds more risky assets. This is important because as we will see later, we are able to show that investor with a DARA tendency would prefer asset that has distribution of returns of a positively skewed nature. This then supports the use of Managed Futures within a portfolio since Managed Futures exhibit significant positive skewness. The following shows the derivation for the Arrow-Pratt coefficient of decreasing absolute risk aversion.

Assume an investor has wealth W and a security with outcomes represented by the random variable Z. Let Z be a fair gamble so that $E(Z) = 0$. Let σ_z^2 equal the variance of Z and $U()$ the investor's utility function. Let W_c be the level of wealth such that the investor is indifferent between having W_c and having wealth W plus the gamble Z. Thus, the two choices are

Choice A	Choice B
W + Z	W_c

By assumption, the investor is indifferent between these positions, thus

$$E[(U(W+Z)] = EU(Wc) = U(Wc) \qquad (B.1)$$

The last equality holds because *Wc* is received with certainty. The difference between *W* and *Wc* is the dollars the investor is willing to give up not to have to face the gamble. If the investor could take out an insurance policy, *W* – *Wc* would be the maximum the investor would be willing to pay to avoid the risk of investment. The greater this difference, the greater the amount of dollars the investor is willing to give up to avoid the gamble. Thus, it is natural to think of $\pi = W - W_c$ as a measure of the investor's absolute risk aversion.

Expanding U(W+Z) in a Taylor series around W, we have[1]

$$U(W+Z) = U(W) + U'(W)[(W + Z) - W] + (1/2)U''(W)\,[(W+Z) - W]^2 + \ldots\ldots$$

Taking the expected value of both sides and ignoring terms involving the third and higher order derivatives, we have

$$E[U(W+Z) \approx E[U(W)] + U'(W)E(Z) + (1/2)U''(W)E(Z-0)^2$$

Recalling that U(W) is a constant and that

$$E(Z-0)^2 = E[Z-E(Z)]^2$$

[1] A Taylor series is a method of approximating a function using its derivatives. Let primes indicate derivatives. For example, U'( ) is the first derivative and U'' ( ) is the second derivative. Let ≈ mean 'approximately equal to'. Then, the Taylor approximation in the vicinity of a is

$$U(X) \approx U(a) + \frac{U'(a)}{1}[X - a] + \frac{U''(a)}{2*1}[X - a]^2 + \frac{U'''(a)}{3*2*1}[X - a]^3 + \ldots\ldots$$

is the variance of Z yields

$$E[U(W+Z)] \approx U(W) + (1/2)U''(W)\sigma_z^2 \qquad \text{(B.2)}$$

Recall that Wc is equal to W - π. Expanding U(W - π) in a Taylor series around W, we have

$$U(Wc) = U(W - \pi) \approx U(W) + U'(W)\,[(W - \pi) - W] + \ldots\ldots$$

Ignoring terms above the first derivative, we have

$$U(Wc) \approx U(W) + U'(W)(-\pi) \qquad \text{(B.3)}$$

From Eqn (B.1) E[U(W+Z)] = U(Wc) and Eqn (B.2) equals Equation (B.3), or

$$U(W) + (1/2)U''(W)\sigma_z^2 = U(W) + U'(W)(-\pi)$$

Rearranging

$$\pi = -(1/2)\,\sigma_z^2\,\frac{U''(W)}{U'(W)}$$

Since (1/2) σ_z^2 is a constant, $A(W) = -U''(W)/U'(W)$ measures the amount of risk aversion. This derives the Arrow-Pratt coefficient of decreasing absolute risk aversion.

However, positive skewness is a necessary condition for decreasing absolute risk aversion (Elton & Gruber, 1991). Arditti (1967) derives that U'''>0 from the Arrow-Pratt coefficient of decreasing absolute risk aversion. The following illustrates this.

Recall Quotient Rule of Partial Differentiation as $\frac{d}{dx}\frac{u}{v} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$, and given π = $-\frac{\sigma^2}{2}\frac{U''(W)}{U'(W)}$ as a decreasing function. By letting v = U'(W) and u = U'' (W) yields:

$$\frac{\partial \pi}{\partial W} = -\frac{U'''}{U'} + (\frac{U''}{U'})^2 \leq 0$$

Implying $\frac{U'''}{U'} \geq (\frac{U''}{U'})^2 \geq 0$. Given U'>0, this follows that U''' $\geq$ 0 under Decreasing Absolute Risk Aversion.

This completes the proof showing that investor's preference underlying the utility of the third order Stochastic Dominance, particularly for the fact that investor having a Decreasing Absolute Risk Aversion would also have a preference for returns with positively skewed returns' distributions.

Chapter 5

An Investigation into the Volatility Dynamics of the International Stock Markets and Managed Futures Indexes and their Effects on Portfolio Performance: a UK investor perspective

5.0 Introduction to the Chapter

The main aim of this chapter is to empirically evaluate the potential benefits to UK investors arising from the ability to include Managed Futures within an already internationally diversified stock portfolio. The benefits of Managed Futures may arise from superior realised portfolio returns and/or lower return volatility, i.e., risk reduction. Given that the potential for risk reduction depends largely on the correlation of Managed Futures returns with existing asset class returns, the recent study on the volatility dynamics of market indexes within portfolio context is of considerable relevance in determining the benefits of Managed Futures.

The method adopted for estimating the benefits of Managed Futures involves comparing the (return-risk) performance of portfolios that include Managed Futures with alternative portfolios consisting of the MSCI North America market indexes. This is because the US market is by far the most influential and tends to lead other markets (Isakov & Porignon 2000), a fact that indicates significant market interdependencies between the US and other leading world stock markets.

The chapter is organised as follows. In Section 5.1, a review is undertaken of the literature that focuses on the magnitude and pattern of interdependencies across international financial markets. Typically, the focus of this research has been on how (primarily, US) market volatility impacts upon other markets. A discussion of the data used for the empirical analysis is undertaken in Section 5.2, and this is followed in Section 5.3 by discussion of the methodology adopted and other econometric modelling issues raised. The main empirical results are presented in Section 5.4 along with a discussion of their implications with respect to the impact of Managed Futures on portfolio performance. A summary of the main findings and concluding remarks are provided in Section 5.5.

5.1 Literature Review

The globalization of financial markets has been accompanied by a growing body of empirical research that has described and analysed the ways in which financial markets in different countries interact. A better understanding of the nature of international market linkages and interactions could be of help to investors and policy makers alike. With respect to policy, aspects of market interaction that promote efficiency could, in principle, be facilitated whereas those with undesirable side effects could be controlled. Likewise, investment and hedging strategies could be more effective if the nature of market interactions were better understood. The existing literature provides evidence that financial markets do in fact have a significant influence upon each other. For example, Koch and Koch (1991) provide compelling evidence regarding the evolution of contemporaneous and lead/lad relationships among eight major national stock markets and the dynamic linkages between them. Moreover, Becker, Finnerty, and Gupta (1990) show that, contrary to the efficient market hypothesis, information generated in the US stock market could be used to trade profitably in Japan.

The October 1987 market crash also drew attention to the possibility that the scope of market interaction might include substantial, and hence policy-relevant, second moment (or variance) linkages. This extension allows testing of the hypothesis that information generated in a given market at time t is useful in terms of predicting the conditional mean and variance in another market at time $t+1$. Hamao, Masulis & Ng (1991) examined spill over effects (i.e., second-moment interdependencies) in 3 major stock markets (New York, Tokyo, and London) using univariate GARCH[1] [2] models. For the period after the October 1987 worldwide stock market crash, they found that volatility spilled over from New York to Tokyo, London to Tokyo, and New York to London. In contrast, no evidence of spill over effects was found in the pre-crash period.

As the October 1987 crash clearly had its origin in the US stock markets, there have been numerous studies focusing on the pattern and the mechanisms by which the US stock market transmitted its volatility to other international stork markets. Theodossiou and Lee (1993), using a multivariate GARCH-M model, found that the US market was the major 'exporter' of volatility. Ng et al. (1991) provided evidence on the volatility spill over transmitted to the stock markets of the Pacific-Basin. Finally, in contrast, Susmel and Engle (1994) examined price and volatility spillovers between

[1] GARCH is the short form for "Generalised Autoregressive Conditional Heteroscedasticity". This is also commonly known as conditional volatility, a technique used to estimate time-varying or conditional variance (or second moments). Further review of GARCH as a methodology, however, can be found in, for example, Engle (1982) and Bollerslev (1986).

[2] The literature review of this section is a general overview on the literatures surrounding the topic of volatility of the international stock markets, which are relevant to the issue addressed in this chapter. There is no discussion on the methodology underlying these literatures. A brief review and description of the methodology used for this chapter, however, can be found in Section 5.3.1 and 5.3.2.

New York and London using hourly returns. They concluded, however, that these spillovers were, at best, small and of short duration.

Nelson (1991) developed the exponential GARCH model (EGARCH) in an attempt to capture the asymmetric impact of shocks on volatility. His findings confirm that, for the US market, negative shocks increase volatility more than positive ones. Cheung and Ng (1992) found a significant leverage effect in a sample of individual stocks that persisted even after conditioning for past volume. In terms of non-US stock markets, Koutmos (1992) found a significant leverage effect in the stock returns of Canada, France and Japan, as did Poon and Taylor (1992) for the UK. Booth and Koutmos (1992) presented similar evidence that volatility in the US and other stock markets responds asymmetrically to their own past volatility (shocks). This suggests that volatility spill over effects may themselves be asymmetric, in the sense that negative shocks in any given market tended to produce a higher volatility spill over in the next market to trade, than did positive shocks of an equal magnitude.

Isakov & Perignon (2000) studied the links between the Swiss stock market and the five largest stock markets in the world (USA, Japan, United Kingdom, Germany and France) in terms of returns and volatility. Their findings reveal that conditional heteroskedasticity is present in every market and also that conditional volatility responds asymmetrically to past shocks. In order to properly take account of these phenomena, Isakov & Perignon (2000) estimated a series of bivariate asymmetric AR (1)-GARCH(1,1) models to measure the links between the Swiss stock market and the five other stock markets. The results indicated that the US market had the strongest influence on the Swiss market in terms of returns and volatility. In order to further investigate how asymmetric volatility interacts and what effect it had on volatility interdependence, Isakov & Perignon (2000) also modelled the dynamics of volatility as a GARCH process that allows for asymmetric effects. Previous studies, e.g., Booth and Koutmos (1995) and Nelson (1991), had assumed constant correlation when using exponential GARCH. Isakov & Perignon (2000) utilised a more flexible specification, known as the BEKK[3] approach to model the GARCH process that was able to take into account asymmetric effects.

The main conclusion of Isakov & Perignon (2000) was that the volatility of Swiss equities very much influenced by events in foreign markets, most significantly the US market. Their research also demonstrated that the volatility transmission mechanism is asymmetric, i.e. bad news (negative innovations) in a given market increases volatility in the other markets more than good news (positive innovations). This is again particularly true for the US market where bad news one day makes the Swiss market very volatile the next day. On the other hand, they find that the Swiss market has a statistically significant but economically weak influence on other foreign markets.

Chelley-Steeley (2000a) investigated whether equity market volatility in one major market was related to volatility elsewhere. She used the daily stock price returns of the Japanese, UK, US, German, French and Italian markets over the period from

[3] See Baba, Engle, Kraft & Kroner (1991) for a discussion on using the BEKK methodology to model the GARCH process. The BEKK methodology modelled conditional volatility by allowing spill-over and asymmetric volatility effect to be incorporated between assets. This means that conditional volatility, within the BEKK methodology, are not only being considered between assets, but conditional volatility, in time of positive and negative returns, of the individual assets are also being modelled. BEKK was not used as a methodology for the GARCH modelling for this chapter, though there was an attempt initially. See Section 7.3.2.2 of Chapter 7 for details. The specification that is used for this chapter to model conditional volatility relating to a portfolio is found in Section 5.3.2.2, in which the motivations are also clearly stated. This specification, which assumed correlation of assets' returns to be constant over time, however, does not capture volatility and asymmetric patterns like the BEKK model. The constant correlation is being captured by the conditional covariance function listed in equation 5.6.

January 1976 to December 1993 to model the daily conditional volatility of equity market wide returns as a GARCH(1,1) process. She also broke down the 18 year period covered by the study into the following sub-periods: 1976-1980, 1981-1985, 1986-1990 and 1991-1993. Comparing the correlation between the conditional variances of these major equity markets in the different sub-periods, revealed that the correlation had increased substantially over the last two decades. Chelley-Steeley (2000a) concluded that the increasingly strong correlations among the conditional variances of major equity markets through time has made it increasingly difficult for investors to reliably diversify their equity return's volatility by undertaking traditional international diversification strategies.

Much of the literature that examines second moment interdependencies appears to have arisen from the need to investigate the volatility effects brought about by the October 1987 crash (Hamao, et. al, 1990). Interestingly, the Oberuc (1992) study that analysed the effect of using Managed Futures in combination with a number of non-US investment portfolio, was also motivated by the events that arose from the October 1987 crash.

Oberuc's (1992) supportive findings relating to the benefits of US-Dollar based Managed Futures within a portfolio during the October 1987 crash may not, of course, be applicable or replicable in the case of future shocks. Using some basic portfolio optimisation techniques, Oberuc's (1992) uses data on 4 European countries over the period from 1979 to 1989 to study portfolio returns when US dollar Managed Futures are included/not included in the portfolio. Each country-specific investment portfolio included stocks, bonds and cash. The countries selected were the UK, Germany, France and Switzerland. As Oberuc (1992) did not specifically show portfolio returns year by year or even month by month, it is hard to see whether the inclusion of Managed Futures actually provided better downside portfolio protection during volatile periods such as the October 1987 crash. Nevertheless, over the 11 years studied, Oberuc's (1992) findings reveal that these portfolios, whether using currency-hedged or un-hedged Managed Futures, seem to perform significantly better (i.e., higher return given the same level of risk) than those portfolios that did not include Managed Futures.

Apart from the October 1987 crash, there has been other volatility inducing shock events worth studying. Amongst these, the most volatile are the bursting of the dotcom and telecom bubbles in 2000, the Russian Bond default and Long Term Capital Management crises of 1998, the September 11th 2001 events and, most recently, the Enron collapse in 2002. No doubt these and future shocks will eventually be fully investigated by academics and this work will clearly be of great relevance to understanding the circumstances and uses of Managed Futures, especially to non-US investors. Isakov & Perignon (2000) commented that while there might not be any systematic conclusions regarding the direction and the magnitude of existing international links, the US market remains the most influential market and that, to greater or lesser degrees tends to lead other markets. And this is especially the case for the October 1987 crash. Their paper also included press reports to illustrate the widespread belief amongst market participants[4] of the existence and importance of international market linkages and volatility.

Moreover, Chelley-Steeley (2000b) analysed the interdependence of such volatility in the major world stock markets and concluded that the increasing correlation of the conditional variances of the world's major equity markets shown in recent years

[4] A recent example is *The Wall Street Journal Europe* which wrote on April 5, 2000: "Yesterday's mayhem on Wall Street is sure to reverberate on European markets today" (Heard in Europe, p.13).

might have made volatility reduction diversification strategies more difficult to achieve. This suggests that international portfolio diversification using US stocks during volatile times might not be as desirable, especially if US stocks are highly correlated with major foreign stock returns during these volatile periods.

One of the consequences of the widely reported evidence that US Stock market volatility tends to spill over into other markets, is that international investors have realised that diversification strategies based upon international investments in traditional asset classes have their limitations. The higher correlation experienced in recent years across markets has motivated the search for alternative types of, derivative-based, investments that have low correlations with existing asset classes. As with most innovations in the financial world, the opportunities for investors to choose alternative investment classes are greatest in the most highly developed US market.

Adopting the rationale of Oberuc (1992) and a similar procedures and methodology used by Isakov & Perignon (2000)[5], the empirical research in this chapter aims to provide a more comprehensive test of the benefits and use of US dollar based Managed Futures within an already internationally diversified portfolio by taking into account the conditional volatility effect and the impact it has on portfolio performance. As compared to Oberuc (1992), the technique and methodology to be employed will show more precisely the functioning and operational mechanisms of the interdependence of returns among the assets and how it affects performance within the portfolio, when US dollar-based Managed Futures are involved.

[5] See footnote 9.

5.2 Discussion of Data for the Empirical Analysis

This section presents the data and the empirical research method used for this chapter. The empirical analysis focuses on the case of a hypothetical UK investor whose portfolio consists solely of equities traded in developed stock markets. This type of portfolio is typical for most pension funds and mutual funds in the UK since both the equities and the currency markets tend to be highly liquid and heavily traded. The UK investor is calibrated to be holding the MSCI EAFE market indexes, i.e., the indexes of major European stock markets weighted by their respective capitalisation values, including the UK and the Developed Far East markets. The case of the UK investor combining the EAFE market index with the MSCI US Index for one portfolio, and the EAFE market index combining with the MAR (Managed Futures) index in another are separately analysed[6] [7]

The MSCI US Index is considered here because previous research, such as Isakov and Porignon (2000) and Theodossiou and Lee (1993), has revealed that the US stock market appears to affect the returns and volatility of other stock market indexes and that this appears to have become more pronounced over recent years. In addition, there is also a need to determine whether Managed Futures behave in a similar manner as the US index with respect to the way it affects the returns and volatility of other assets. Previous research such as Edwards and Liew (1999) and Edwards and Caglayan (2001) have consistently shown that Managed Futures are lowly correlated with other traditional investments.

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[6] Table 3.1(A) of Chapter 3 provides details of The MAR Trading Advisor Qualified Universe Index.

[7] A summary of the Description of the data of this chapter includes the reasons for the use of the time period, can be found in table 3.2 of chapter 3. Section 3.2.1.2 of the same chapter explains the choice and the selection of data used in this chapter, while Table 3.4(B) provides the summary of the descriptive statistics of these data for the entire sample period.

The empirical analysis also attempts to assess whether Managed Futures provide significant incremental benefits, when compared with the MSCI North America index. As the highest frequency data points for the Managed Futures index are available on a monthly basis, the observational frequency of the other stock market indexes are therefore also fixed on a monthly basis. Our sample study period is from January 1980 to December 2001, which gives a total of 265 data observations for each of the 3 market indexes.

All the returns of the market indexes are in £'s (Sterling) terms converted using the Sterling pound/US Dollar spot rates. The EAFE and the MSCI North America stock index information are taken from Data-Stream International, while the Managed Futures index was obtained from a data vendor company called Zurich Financial Services. These indexes are all price indexes, do not include dividends and are all market value weighted. The returns are computed as $r_{it} = \log(P_{it}) - \log(P_{it-1})$.

5.3 Research Methodology

This section discusses the research methodology[8] used for this chapter. Section 5.3.1 should first discuss some research design issues related to the estimation of the conditional variance of the individual market index. This is then followed by section 5.3.2 which will discuss the conditional volatility effect to emerge from using these market indexes within a portfolio. The analysis of section 5.3.2 should discuss the effect within a portfolio that uses the EAFE and Managed Futures indexes and another portfolio that use the EAFE and the United States indexes.

[8] This approach is similar to that found in Isakov and Porignon (2000).

5.3.1 Conditional Volatility of the individual Market Index

In this section, conditional variances of market indexes are estimated. The results gathered from the estimation will form the main basis to estimate the conditional volatility effect on portfolio performance[9] when these market indexes are later used in a portfolio. This will be discussed in Section 5.3.2. However, to first estimate the conditional variances of market indexes, the univariate GARCH (Generalised Autoregressive Conditional Heteroscedasticity) effect of these individual indexes is examined using the following specification. Equation 5.1 represents the conditional mean function while equation 5.2 represents the conditional variance function.

$$r_t = a_o + a_1 r_{t-1} + a_2 r_{t-2} + a_3 r_{t-3} + \varepsilon_t \quad (5.1)$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \quad (5.2)$$

The conditional mean equation is modelled as an auto-regressive process of order three (i.e., AR(3))[10]. The conditional variance equation, however, is modelled as

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[9] This procedure is similar to that of Isakov & Porignon (2000), where the main aim is to first identify the presence of significant conditional variance within the individual market indexes before exploring further the conditional volatility and the effect emerged from using the market indexes in a portfolio. Isakov & Porignon (2000) use BEKK, a methodology that consider asymmetric variance and spill over effect when modelling conditional volatility. This chapter, however, adopted the assumption of constant correlation when modelling conditional volatility. See also footnote 3.

[10] See Appendix 5.1 for a discussion of the procedure used to run the auto-regression and the reason as to why AR(3) is chosen.

Table 5.1 : Descriptive statistics of residuals (generated from AR(3)) for the 24 samples periods for Managed Futures, MSCI EAFE and MSCI US indexes

Sample Periods	Managed Futures					EAFE					US				
(No. of data points)	mean	var	*Skew**	*Kurt**	Q(12)	mean	var	*Skew**	*Kurt**	Q(12)	mean	var	*Skew**	*Kurt**	Q(12)
1 (238)	[a]4.219	0.0029	*1.359*	*3.448*	8.014	[a]-4.219	0.0023	*-0.722*	*2.045*	9.685	[b]1.688	0.0024	*-0.606*	*1.576*	4.829
2 (239)	[b]1.681	0.0029	*1.366*	*3.481*	7.929	[a]3.36	0.0023	*-0.721*	*1.947*	9.423	[b]2.521	0.0024	*-0.605*	*1.526*	4.644
3 (240)	[b]-2.929	0.0029	*1.365*	*3.498*	8.027	[a]2.09	0.0023	*-0.727*	*1.941*	9.300	[b]2.092	0.0024	*-0.607*	*1.546*	4.660
4 (241)	[a]3.75	0.0029	*1.372*	*3.525*	8.036	[a]3.33	0.0023	*-0.731*	*1.962*	9.274	[d]2.891	0.0025	*-0.584*	*1.495*	4.934
5 (242)	[b]-1.66	0.0029	*1.378*	*3.550*	8.002	[d]6.91	0.0023	*-0.722*	*1.931*	8.207	[a]-8.299	0.0025	*-0.582*	*1.493*	4.717
6 (243)	[b]-1.653	0.0029	*1.370*	*3.537*	7.968	[c]2.3	0.0023	*-0.727*	*1.951*	8.066	[a]-4.132	0.0025	*-0.590*	*1.520*	4.835
7 (244)	[b]1.235	0.0028	*1.377*	*3.565*	7.833	[a]-4.115	0.0023	*-0.731*	*1.972*	7.997	[a]-4.115	0.0024	*-0.592*	*1.538*	4.817
8 (245)	[a]-8.197	0.0028	*1.384*	*3.595*	7.865	[b]-1.23	0.0023	*-0.721*	*1.946*	7.723	[a]-4.098	0.0024	*-0.585*	*1.537*	4.755
9 (246)	[b]-1.126	0.0028	*1.385*	*3.618*	7.881	[a]8.16	0.0023	*-0.729*	*1.959*	7.937	[c]1.133	0.0024	*-0.592*	*1.538*	4.859
10 (247)	[b]1.626	0.0028	*1.387*	*3.645*	7.908	[a]-8.13	0.0023	*-0.716*	*1.880*	8.291	[a]-1.22	0.0024	*-0.587*	*1.540*	5.173
11 (248)	[b]-2.024	0.0028	*1.394*	*3.674*	7.941	[d]-7.515	0.0023	*-0.714*	*1.894*	8.229	[a]1.619	0.0024	*-0.579*	*1.535*	5.103
12 (249)	[b]-4.032	0.0028	*1.382*	*3.636*	7.961	[b]-3.226	0.0023	*-0.707*	*1.898*	8.486	[a]1.21	0.0024	*-0.566*	*1.466*	5.208
13 (250)	[d]5.295	0.0028	*1.376*	*3.636*	8.088	[a]-8.032	0.0022	*-0.700*	*1.899*	8.270	[d]5.016	0.0024	*-0.555*	*1.448*	5.209
14 (251)	[a]-8	0.0028	*1.380*	*3.666*	8.143	[a]4	0.0022	*-0.705*	*1.918*	8.244	[f]-3.47	0.0024	*-0.559*	*1.467*	5.329
15 (252)	[a]3.984	0.0028	*1.381*	*3.687*	8.176	[b]-2.789	0.0023	*-0.693*	*1.843*	8.742	[a]-3.984	0.0025	*-0.556*	*1.407*	5.620
16 (253)	[a]7.937	0.0028	*1.375*	*3.686*	8.086	[b]-1.19	0.0023	*-0.677*	*1.794*	8.570	[b]-1.19	0.0025	*-0.537*	*1.339*	5.301
17 (254)	[b]1.581	0.0028	*1.382*	*3.707*	8.120	[b]3.557	0.0023	*-0.686*	*1.781*	8.547	[a]7.905	0.0025	*-0.539*	*1.330*	5.394
18 (255)	[b]2.362	0.0028	*1.385*	*3.735*	8.165	[e]-1.535	0.0023	*-0.667*	*1.744*	8.506	[b]-2.362	0.0025	*-0.538*	*1.350*	5.342
19 (256)	[b]-2.745	0.0027	*1.389*	*3.762*	8.191	[a]3.922	0.0023	*-0.667*	*1.743*	8.494	[a]7.843	0.0025	*-0.535*	*1.359*	5.204
20 (257)	[d]-4.066	0.0027	*1.395*	*3.788*	8.310	[b]-3.125	0.0023	*-0.656*	*1.732*	9.274	[b]1.172	0.0024	*-0.528*	*1.356*	5.129
21 (258)	[a]-3.891	0.0027	*1.401*	*3.816*	8.362	[a]3.891	0.0023	*-0.642*	*1.704*	9.275	[a]-3.891	0.0025	*-0.518*	*1.274*	4.462
22 (259)	[c]1.654	0.0027	*1.407*	*3.842*	8.392	[b]2.326	0.0023	*-0.645*	*1.627*	8.216	[a]-3.876	0.0025	*-0.502*	*1.164*	3.216
23 (260)	[b]-1.935	0.0027	*1.400*	*3.831*	8.559	[d]-5.358	0.0023	*-0.667*	*1.627*	7.552	[b]-1.158	0.0025	*-0.509*	*1.186*	3.308
24 (261)	[a]-7.692	0.0027	*1.403*	*3.832*	8.451	[b]1.538	0.0023	*-0.677*	*1.625*	7.229	[b]-2.692	0.0025	*-0.508*	*1.153*	3.927

Note: * indicates that Normality for the residual series in all sample periods are rejected as the ratio of Kurtosis and skewness with their respective standard errors are either <-2 or >2; ([a]) indicates that the values need to be multiplied by 10^{-9}; ([b]) by 10^{-8}; ([c]) by 10^{-18}; ([d]) by 10^{-19}, ([e])by 10^{-4} and ([f])by 10^{-20}

GARCH(1,1)[11] in which the conditional variance, σ_t^2 , is a function of its own past, and the past value of the squared residual.

Table 5.1[12] (shown in the previous page) shows the descriptive statistics of the residuals of the 3 indexes using the AR(3) process. The kurtosis shows that the residual series in all sample periods show no signs of normality, and they appear to have thicker tails than the normal distribution[13]. The Box-Ljung statistics of order 12, shows that the residual series in the entire sample period fails to exhibit serial correlation. Table 5.2[14] shows the results of estimating equations 5.1 & 5.2 for the indexes.

Table 5.2: The average coefficient estimates of AR(3)-GARCH(1,1) of the 3 market indexes generated for the 24 in-sample periods

AR(3) in (5.1) is used to generate GARCH(1,1)

$$r_t = a_o + a_1 r_{t-1} + a_2 r_{t-2} + a_3 r_{t-3} + \varepsilon_t \qquad \text{From (5.1)}$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \qquad \text{From (5.2)}$$

[11] Appendix 5.1 above verified that AR(3)-GARCH(1,1) does appear to give the best specifications for the three market indexes. Further likelihood tests were conducted for the full sample period of the three indexes, by comparing the maximum likelihood values for AR(3)-GARCH(1,1) and AR(3)-GARCH(1,3). The results show that increasing the lags, do not improve the maximum likelihood values significantly. Details of the results are available upon request.

[12] Appendix 5.2 shows the parameters estimates for AR(3) for the 3 indexes for the 24 sample periods.

[13] According to Choudhry (1996), and Bollerslev et al. (1992), stock returns of non-normal unconditional sampling distributions tend to exhibit skewness and excess kurtosis. However, as is shown by Baillie and DeGennaro (1990) and Bollerslev (1987), distribution assumption of conditional normality may be inappropriate if the residuals series are leptokurtic. In such cases, the assumption of a conditional student-t density may be more appropriate. The study in Choudhry(1996) used both the conditional normality and the t-density estimations. Both estimations, however, show similar results. Moreover, based on Joseph (2003) there is no conclusive evidence on the statistical distribution that is likely to provide the best fit for Univariate GARCH modelling.

[14] This Table gives the average value of the 24 sets of coefficients generated by AR(3)-GARCH(1,1) for the 24 in-samples time periods for the three market indexes. The estimations of AR(1)-GARCH(1,1), AR(2)-GARCH(1,1) and AR(3)-GARCH(1,1) for the entire 24 periods for the 3 market indexes can be found in Appendix 5.3A to 5.3C (estimates for MSCI US index), Appendix 5.4A to 5.4C (estimates for MSCI EAFE index) and Appendix 5.5A to 5.5C (estimates for Managed Futures).

Table 5.2 (con't): The average coefficient estimates of AR(3)-GARCH(1,1) of the 3 market indexes generated for the 24 in-sample periods

Average coefficient estimates for AR(3) using equation (5.1)

	US	MAR	EAFE
a_0	0.01238 (3.610833)***	0.01702 (4.54208)***	0.00962 (2.99583)***
a_1	0.13791 (2.15833)**	-0.11898 (-1.89250)*	0.10295 (1.61667)
a_2	-0.05276 (-0.81792)	-0.11832 (-1.88167)*	0.00753 (0.1175)
a_3	-0.02200 (-0.35708)	-0.05844 (-0.95583)	-0.04385 (-0.68333)

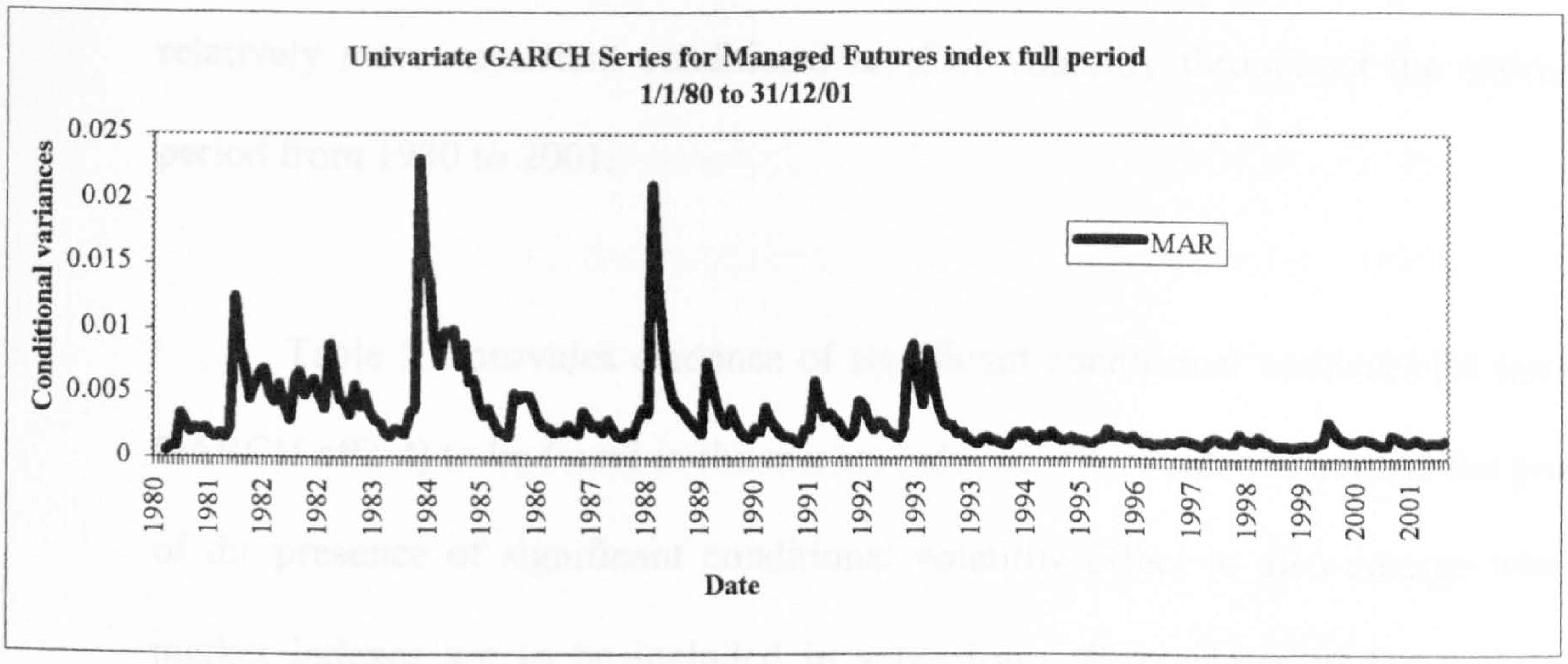
Average coefficient estimates for AR(3)-GARCH(1,1) using equation (5.2)

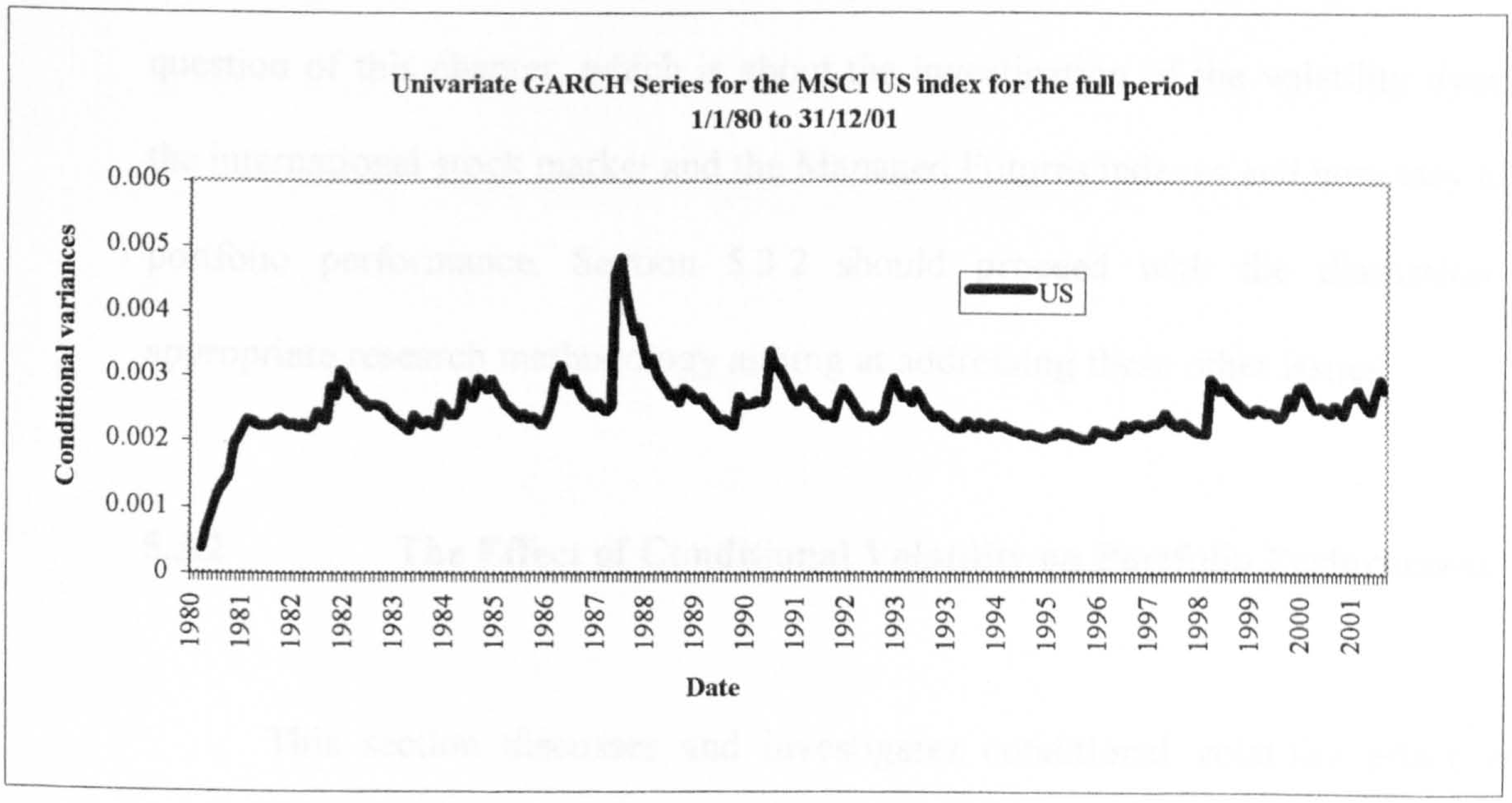
	US	MAR	EAFE
ω	0.000357 (1.68302)*	0.000343 (2.83715)***	0.000428 (1.9302)*
β	0.81007 (13.532)***	0.62719 (14.7374)***	0.78154 (25.5546)***
α	0.04732 (0.5004)	0.30911 (5.4085)***	0.03167 (0.3120)
Avg MLE values	**623.1096**	**615.1842**	**632.7688**

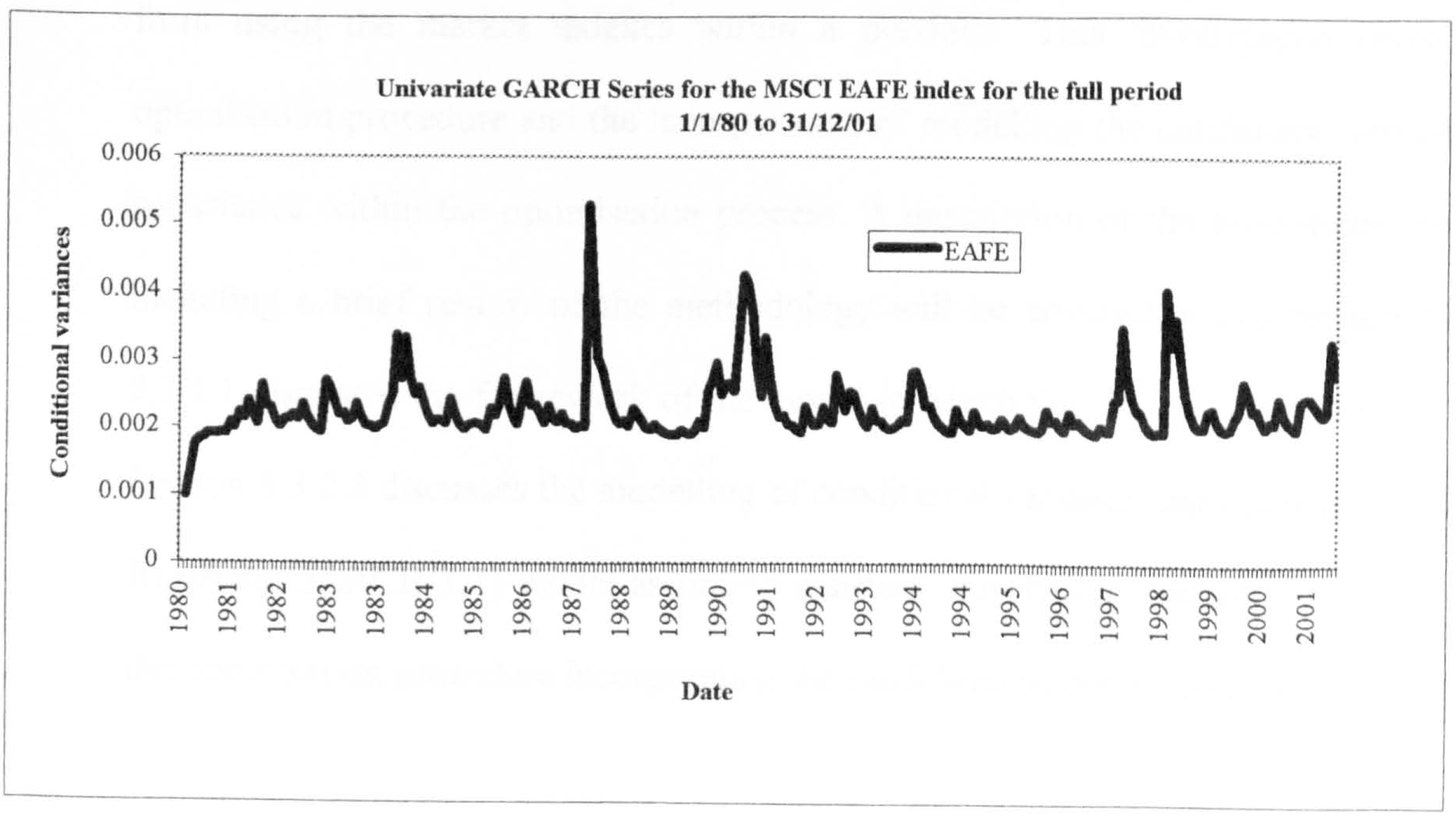
Notes: 1) Ave MLE is Average Maximum Likelihood Estimates. 2) values in bracket are the average t statistics values; 3) *** indicates p values for the t-statistics values concerned is significant at 0.01; ** at 0.05 and * at 0.10.

The Table 5.2 estimates show that Managed Futures have the greatest ARCH effect (α) compared with the US and EAFE index. However, it appears to have the least GARCH effect (β) when compared to the US and EAFE indexes. Figure 5.1 provides a graphical comparison of the conditional variances of the three market indexes for the entire sample period. It is quite clear that Managed Futures have quite high time variation in its conditional variance until about 1994, after which it begins to show signs

Figure 5.1: Graphical comparison of univariate GARCH (1,1) for the 3 market indexes







of more stability. However, the US and the EAFE indexes appear to show rather relatively more consistent conditional level of volatility throughout the entire sample period from 1980 to 2001.

Table 5.2 provides evidence of significant conditional variances (in term of the GARCH effect) to be found in the market indexes. This evidence implies the possibility of the presence of significant conditional volatility effect to also emerge when these market indexes are to be included in a portfolio. This relates to the main research question of this chapter, which is about the investigation of the volatility dynamics of the international stock market and the Managed Futures indexes and how they affect the portfolio performance. Section 5.3.2 should proceed with the discussion of the appropriate research methodology aiming at addressing these other issues.

5.3.2 The Effect of Conditional Volatility on Portfolio Performance

This section discusses and investigates conditional volatility effect emerged from using the market indexes within a portfolio. This investigation involves an optimisation procedure and the incorporation of modelling the conditional variance and covariance within the optimisation process. A description of the procedures involved, including a brief review of the methodology will be covered in this section. Section 5.3.2.1 discusses the framework of the model in which the analysis will be based upon. Section 5.3.2.2 discusses the modelling of conditional variance and covariance using the Bivariate GARCH(1,1) model assuming constant correlation. Section 5.3.2.3 describes the optimisation procedure incorporating the modelling as described in Section 5.3.2.2.

5.3.2.1 Conditional Volatility within Multivariate-GARCH(1,1)

To model the time variability and any predictability in the conditional covariance (as well as the conditional variances) a multivariate setting is needed. Ibrahim (1997) formulates the following set up suited for the task of predicting the conditional variances and covariance.

ε_t is defined as an N-dimensional vector of conditional mean zero random variables with an N x N conditional variance-covariance matrix, $\mathbf{H}_t$, that can change over time. The relationship is being depicted below as equations (5.3) and (5.4) respectively. Hence,

$$\varepsilon_t \mid \psi_{t-1} \sim \text{MD}\,(0,\ \mathbf{H}_t) \qquad (5.3)$$

$$\mathbf{H}_t = \text{G}\,(\psi_{t-1}; \mathbf{Z}) \qquad (5.4)$$

is being defined as a multivariate-GARCH process, where MD is a multivariate distribution and G is a non-negative function of elements in the information set ψ_{t-1} and the parameter space $\mathbf{Z}$. Usually ε_t is taken as the unexpected component (or residual) resulting from modelling the first moment of some other stochastic process $\mathbf{Y}_t$, where

$$\mathbf{Y}_t = f(X_{t-1}; C) + \varepsilon_t, \qquad (5.5)$$

and $f(X_{t-1}; C)$ is the hypothesised mean of $\mathbf{Y}_t$ as a function of the parameter vector C and the set of endogenous and exogenous variables X_{t-1} observed at time t-1 and included in the information set ψ_{t-1}.

In this analysis, the research in this chapter models expected returns by using the Vector-Autoregression (VAR) methodology of order q. The appropriate lag or order q of VAR is tested and results are discussed in section 5.4. Therefore, the hypothesised mean of $\mathbf{Y}_t$, $f(X_{t-1};C)$ is assumed to take a VAR format.

Guided by the preliminary univariate analysis in which the conditional variance is modelled by a GARCH(1,1) process, the empirical analysis proceeds to formulate and parameterise the function G, in terms of the information set ψ_{t-1} and the parameter space $\mathbf{Z}$. Section 5.3.2.2 in the following should now review the specifications of the Constant Correlation Bivariate GARCH(1,1) ("CC-GARCH" or "CC-GARCH(1,1)" thereafter) model that accounts for conditional volatility within a portfolio context. This will subsequently be applied in the variance and covariance matrix as stated in this section.

5.3.2.2 The Constant Correlation Bivariate-GARCH(1,1) Model

Bollerslev (1990) proposed a model with constant correlation for the five nominal European versus dollar exchange rates, i.e., the German Mark, French Franc, Italian Lira, Swiss France and the British Pound. He finds evidence of higher co-movement among these currencies over the European Monetary System (EMS) implementation period. The significantly higher co-movement, compared with the pre-EMS free float period, is contributed by the relatively higher correlation observed after the EMS implementation.

The CC-GARCH model restricts the conditional covariance between two assets to be proportional to the product of the conditional standard deviations, while the conditional variances follow GARCH (p,q) processes. The product of the conditional standard deviations is made up from two univariate GARCH(1,1) equations of the two market indexes. Here, the returns of the market indexes are captured only by the correlation of the two market indexes, which is assumed to be constant over time.

Bollerslev (1990) gives the following specification as the bivariate GARCH system of the Constant Correlation model.

$$\begin{aligned} h_{11t} &= c_1 + a_{11}\,\varepsilon_{1,t-1}^2 + b_{11}\,h_{11,t-1} \\ h_{12t} &= \rho_{12}\sqrt{h_{11,t}}\,\sqrt{h_{22,t}} \\ h_{22t} &= c_3 + a_{33}\,\varepsilon_{2,t-1}^2 + b_{33}\,h_{22,t-1} \end{aligned} \tag{5.6}$$

The CC-GARCH model proposed by Bollerslev (1990) simplifies the estimation and inference procedures because the model only requires N(N+5)/2 parameters whereas other GARCH specifications incorporate more parameters. The necessary and sufficient conditions for the model to be well defined and $\mathbf{H}_t$ to be positive definite are that each of the conditional variances is positive and that the constant matrix of conditional correlation is non-negative definite.

Another motivation for the use of the CC-GARCH model in the empirical analysis of this chapter arises from previous research. For example, Edwards and Liew (1999) and Edwards and Caglayan (2001) show that Managed Futures are relatively lowly or may even be negatively correlated with other traditional investments such as stock and bonds. Similar to these authors, the empirical research in this chapter also reports the low or negative correlation of returns of Managed Futures (MAR) index with either the EAFE or the US index. However, correlations may or may not vary over time.

The empirical research in this chapter provides evidence suggesting that these low or negative correlations of returns of Managed Futures with either of these two other market indexes appear also to be constant over time[15]. Therefore, it is not necessary to model the time variation of correlations, which is why the CC-GARCH model is used in this chapter. However, unlike Bollerslev (1990), the analysis in this chapter will not be separated into different blocks of time periods. Instead, the analysis focuses on investigating the volatility dynamics of the market indexes and their impacts on portfolio performance. The incremental benefits of Managed Futures within the MAR/EAFE Indexes portfolio (when compared with the US/EAFE Indexes portfolio), will be assessed by comparing the performances of these portfolios.

The CC-GARCH(1,1) model is estimated using returns of portfolios consisting of pairs of market indexes. The log-likelihood function is maximised using the non-linear optimisation algorithm of Berndt et al. (1974), assuming a multivariate-normal distribution. The log-likelihood function is given by

$$L_t(\Theta) \equiv \ln(2\pi) - 0.5[\ln|\mathbf{H}_t| + (\varepsilon_t'\mathbf{H}_t^{-1}\varepsilon_t)]. \qquad (5.7)$$

The maximisation is performed on a rolling basis. The model is first estimated using the in-sample time period from January 1980 to December 1999. The optimal

[15] Appendix 5.6 shows the correlations of returns for the three market indexes for the various time periods block. It also describes and explains the relevant test, used to investigate the stability of the correlations of returns of the three market indexes, across the various time period blocks.

weights that result from the optimisation procedures are applied to the asset portfolio for the following month, which is the first month of the out-of-sample period. The next step in the rolling procedure, appends the actual return observations of this month to previous observations to form a newly expanded in-sample period. Estimation is then conducted to produce a set of optimal weights for the following month in the out-of-sample period. This process is repeated until observations end in November 2001. The discussion of the optimisation process, which incorporate the conditional variance and covariance inputs from the CC-GARCH(1,1) process and follows that of the rolling procedures, should now follow.

5.3.2.3 The Optimisation Procedure

This section discusses the portfolio optimisation procedure in which details on how inputs of variance and covariance of the market indexes, as generated by the CC-GARCH(1,1) technique and discussed in Section 5.3.2.2, are incorporated.

In attempting to assess whether there are benefits arising from the use of Managed Futures within an already internationally diversified portfolio, monthly portfolio returns[16], as performance benchmarks, are used. The empirical study therefore focuses on the portfolio optimisation procedure that an investor would undertake to estimate expected returns, variances and covariance for the vector of assets considered as inputs to the optimisation procedure. Solving the optimisation procedure will yield a vector of 'optimal' weights that represents a prescription to follow in order to achieve the highest return for a given level of risk (variance) or the lowest risk for a given level of return.

[16]The more commonly used Sharpe ratio is not used here because of potential biases in measuring portfolio returns when they exhibit significant skewness (see, The Deutsche Bank Global Market Research, 2002, p15-18).

The estimates of such weights or inputs were originally solved in a single period model framework, see Grubel (1968), Levy and Marshall (1971) and Elton and Gruber (1976). However, multi-periods time variations of the second moments are considered in this chapter. Studies of such time variation of the second moments have been used in a number of different contexts and applications. Kroner and Ng (1998) estimate such effects between big and small firms. Ibrahim (1997) applies it to the context of the UK stock and bond markets. More recently, Isakov and Porignon (2000) and Kasch-Haroutounian and Price (2001), use the MSCI market indexes in different countries to investigate possible , taking into account the time variation of the second moment.

Following Isakov and Porignon (2000) and Kasch-Haroutounian and Price (2001), this chapter studies the possible dynamic of the Managed Futures index with the underlying MSCI market indexes. As monthly portfolio returns are used as a basis of performance benchmark to assess the benefits of Managed Futures within an already internationally diversified portfolio, the portfolio optimisation is therefore constructed as follows, together with the asset allocation problem and the constraints as 5.8 and 5.9a and 5.9b define as:

$$\text{Minimise: } \omega_t^{'}\mathbf{H}_t\omega_t \qquad (5.8)$$

$$\text{Subject to: } E_{t-1}(r_{p,t}) = \omega_t^{'}E_{t-1}(r_t) = R, \qquad (5.9a)$$

$$\omega_t^{'}\mathbf{I} = 1 \qquad (5.9b)$$

where $r_{p,t}$ is the returns on a portfolio formed with the vector of weights ω_t and the vector of individual market index returns r_t, $\mathbf{I}$ is a vector of ones, and $\mathbf{H}_t$ is the conditional variance-covariance matrix of the particular two market indexes considered.

The generation and the modelling of the conditional variance and covariance series based on CC-GARCH(1,1) models are discussed and described in Section 5.3.2.2. These series are stored as the conditional variance-covariance matrix in $\mathbf{H}_t$ and used as inputs for the optimizations problem that solve for the proportions of MAR, MSCI EAFE and MSCI US indexes to be held in the optimal portfolio. The portfolio performance is assessed based on the 'forward rolling window' approach. Firstly, the CC-GARCH model is used to estimate the one-step-ahead variance-covariance matrix $\mathbf{H}_{t+1}$. This, together with one-step-ahead estimate of expected returns entered into the optimisation algorithm outlined above. The output is $\hat{w}_{t+1}$, which is estimate of weights that describe the optimal portfolio for period $t+1$. This procedure is rolled over period-by-period until November 2001 starting with estimation over the in-sample period of date, January 1999 to December 1999.

These weights are then applied to the asset portfolio for the following one month period in the out sample. This goes on to include the next in-sample estimation that includes this out-sample one-month period and then obtain the weights derived from the optimisations and use them in the one month following the end-of-out-sample period. This rolling process goes on until the in-sample estimation end date of November 2001. The out sample period is from January 2000 to December 2001, a total of 24 periods.

5.4 Discussion of Results

There are two parts to the discussion of the results[17]. Firstly, the GARCH(1,1) specification effects in the in-sample data sets are examined. These results provide some insights on how the weighting/proportions of the assets are derived. Secondly, the discussion of the results should focus on examining the results of the portfolio performance in the out sample. There are 24 in-sample periods used to estimate the coefficients of the CC-GARCH(1,1) process. These 24 sets of coefficients are then used to construct the EAFE/US indexes portfolio and the EAFE/Managed Futures indexes portfolio, as will be discussed in Table 5.3.

Table 5.3 presents the average values of the estimated coefficients of the CC bivariate GARCH model using Vector-Autoregression (VAR) of order 3 and 1 for the EAFE/MAR portfolio and the EAFE/US portfolio[18] [19]. VAR specification of the mean equations allows for the analysis of return transmission, in the sense that past returns of one asset are allowed to affect expected returns of another asset. This effect is captured by the coefficient attached to past return of asset j in the regression equation of another asset i[20]. The coefficient captures the sensitivity of asset i's expected returns to the past returns of asset j, i.e., it captures the extent of transmission of information from past returns of one asset to expected returns of the other. Therefore, return transmission is captured, or allowed for, by the adopted VAR methodology.

The residuals series generated from the VAR captured the information on the return transmission between the two assets. It gives implications on how the two assets' return are related to each other. Table 5.4A and 5.4B (the page following table 5.3) present descriptive statistics of the residuals (for the two indexes underlying the two separate portfolios) of the VAR used to model the mean equations. These residual series

[17] The RATS software package is used to help generate the coefficients or parameters needed for use in both the univariate GARCH(1,1) and the CC-Bivariate GARCH(1,1) models.

[18] See Appendix 5.7 regarding the procedure used to determine the order of VAR that have been selected for the two portfolios to run the CC-Bivariate GARCH(1,1).

[19] See Appendix 5.8A to 5.8C and 5.9A to 5.9C for the estimates of the 24 individual periods run by VAR(1), VAR(2) and VAR(3) individually on both the EAFE/US portfolio and EAFE/MAR portfolio. These estimates provide support for our decision to use the orders of VAR for the portfolios to run the CC-bivariate GARCH(1,1) model.

are used to estimate the CC-bivariate GARCH(1,1) model. Table 5.4A and 5.4B also show that the residuals exhibit significantly non-normality[21].

Table 5.3: Constant correlation bivariate GARCH(1,1) modelling: the average of the parameter estimation for the 24 in-sample periods

1) Model specification

$$h_{11t} = c_{11} + a_{11}\, \varepsilon^2_{1,t-1} + b_{11}\, h_{11,t-1}$$

$$h_{12t} = \rho_{12} \sqrt{h_{11,t}} \sqrt{h_{22,t}}$$

$$h_{22t} = c_{22} + a_{22}\, \varepsilon^2_{2,t-1} + b_{22}\, h_{22,t-1}$$

i) The EAFE/ MAR indexes portfolio (h_{11} = EAFE; h_{22} = MAR) (Using VAR (3))

	c_i	a_i	b_i	ρ_{12}
EAFE (h_{11})	0.000959 *(1.6012)*	0.092819 *(0.9056)*	0.480114 *(2.1696)***	0.065552 *(0.9747)*
MAR (h_{22})	0.00034 *(3.0534)****	0.2641 *(4.202)****	0.660823 *(15.8946)****	

Average MLE=1247.512

ii) The EAFE/US indexes portfolio (h_{11} = EAFE; h_{22} = US) (Using VAR (1))

	c_i	a_i	b_i	ρ_{12}
EAFE (h_{11})	0.00120 *(1.8620)**	0.125725 *(1.3658)*	0.35735 *(1.4213)*	0.57716 *(16.8312)****
US (h_{22})	0.000731 *(1.4626)*	0.090661 *(0.8953)*	0.618900 *(4.2245)****	

Average MLE=1312.33

Notes: 1) Values in bracket are average t statistics; 2) *** indicates the p values of the t statistics values are significant at 0.01; ** at 0.05 and * at 0.10.

[20] Appendix 5.10 defines the VAR for the indexes underlying the EAFE/US and the EAFE/MAR portfolios. It also shows the parameter estimates for the 24 in sample periods. For simplicity, we have defined i=1 and i=2 to denote the two different indexes underlying the portfolios, instead of asset i and j as mentioned in the text.

[21] See footnote 13 for the discussion regarding the distributional pattern of the residual series.

Table 5.4A : Descriptive statistics of residuals (generated from VAR(1)) for the 24 samples periods: The case of EAFE/US portfolio

Sample Periods (No. of data points)	US mean	US variance	US Skew*	US Kurt	US Q(12)	EAFE mean	EAFE variance	EAFE Skew*	EAFE Kurt	EAFE Q(12)
1 (239)	^{b}4.184	0.00241	*-0.62*	1.57335	6.085	^{b}1.674	0.00222	*-0.6076*	1.65308	14.204
2 (240)	^{b}-1.667	0.00244	*-0.62*	1.52164	5.663	^{b}1.667	0.00225	*-0.6107*	1.57773	13.585
3 (241)	^{b}-2.49	0.00243	*-0.62*	1.5414	5.678	^{d}-1.44	0.00225	*-0.6213*	1.57354	13.11
4 (242)	^{b}-2.479	0.00246	*-0.61*	1.508	6.191	^{b}-2.066	0.00225	*-0.6268*	1.59468	13.097
5 (243)	^{b}-3.704	0.00246	*-0.61*	1.50531	5.801	^{a}-4.115	0.00225	*-0.6243*	1.57654	11.492
6 (244)	^{b}-2.459	0.00245	*-0.61*	1.52756	5.847	^{a}-8.197	0.00224	*-0.6306*	1.59631	11.27
7 (245)	^{b}-4.082	0.00244	*-0.61*	1.54641	5.822	^{b}1.633	0.00224	*-0.6346*	1.61509	11.21
8 (246)	^{b}-1.626	0.00244	*-0.61*	1.54386	5.817	^{b}-3.252	0.00224	*-0.6247*	1.59251	10.637
9 (247)	^{b}-1.215	0.00244	*-0.61*	1.54079	5.868	^{a}-4.049	0.00223	*-0.6327*	1.60288	10.926
10 (248)	^{b}1.201	0.00244	*-0.61*	1.5417	6.017	^{b}2.823	0.00225	*-0.6294*	1.54296	11.177
11 (249)	^{b}5.221	0.00243	*-0.6*	1.54229	5.982	^{a}8.032	0.00224	*-0.6271*	1.55709	11.095
12 (250)	^{d}7.772	0.00244	*-0.59*	1.47383	6.283	^{b}2.4	0.00223	*-0.6215*	1.56066	11.269
13 (251)	^{b}-2.39	0.00244	*-0.58*	1.45609	6.253	^{c}-1.189	0.00223	*-0.6159*	1.56417	11.224
14 (252)	^{b}1.19	0.00243	*-0.58*	1.47659	6.491	^{b}-1.191	0.00222	*-0.6221*	1.58297	11.164
15 (253)	^{a}-3.953	0.00245	*-0.57*	1.40995	6.795	^{b}-1.976	0.00223	*-0.6128*	1.51672	11.852
16 (254)	^{b}-2.362	0.00245	*-0.56*	1.35089	6.508	^{d}-7.103	0.00224	*-0.5958*	1.47223	11.723
17 (255)	^{b}-1.569	0.00247	*-0.56*	1.34674	6.553	^{b}-1.961	0.00224	*-0.6033*	1.46393	11.58
18 (256)	^{b}4.297	0.00246	*-0.56*	1.36403	6.51	^{b}-1.563	0.00224	*-0.5972*	1.44518	11.731
19 (257)	^{b}1.167	0.00245	*-0.55*	1.37486	6.409	^{b}1.556	0.00224	*-0.5881*	1.43392	11.476
20 (258)	^{a}-3.876	0.00245	*-0.55*	1.3759	6.414	^{a}-7.752	0.00224	*-0.5791*	1.42486	12.375
21 (259)	^{a}-3.861	0.00247	*-0.54*	1.29638	5.885	^{b}3.089	0.00224	*-0.5671*	1.39914	12.367
22 (260)	^{b}2.692	0.00249	*-0.52*	1.18895	4.855	^{b}1.538	0.00228	*-0.5604*	1.29565	11.573
23 (261)	^{a}-7.663	0.00249	*-0.53*	1.21142	5.031	^{d}-2.659	0.00228	*-0.5722*	1.29992	10.879
24 (262)	^{e}-2.76	0.00249	*-0.53*	1.20853	6.201	^{e}-1.725	0.00228	*-0.5716*	1.30077	10.447

Note: (*) indicates that Normality for the residual series in all sample periods are rejected as the ratio of Kurtosis and Skewness with their respective standard errors are either <-2 or >2; (^{a}) indicates that the values need to be multiplied by 10^{-9}; (^{b}) by 10^{-8}; (^{c})by 10^{-18}; (^{d})by 10^{-19} , (^{e}) by 10^{-4} and (^{f}) by 10^{-20}

Table 5.4B : Descriptive statistics of residuals (generated from VAR(3)) for the 24 samples periods
The case of EAFE/MAR portfolio

Sample Periods	Managed Futures					EAFE				
(No. of data points)	mean	variance	*Skew**	*Kurt**	Q(12)	mean	variance	*Skew**	*Kurt**	Q(12)
1 (238)	[a]-8.439	0.00288	*1.3578*	*3.5290*	6.6210	[c]-1.874	0.00223	*-0.7017*	*1.9328*	7.5740
2 (239)	[a]-4.202	0.00287	*1.3661*	*3.5562*	6.4760	[b]-1.681	0.00225	*-0.7055*	*1.8564*	7.3570
3 (240)	[a]-8.368	0.00286	*1.3639*	*3.5728*	6.5610	[b]2.092	0.00226	*-0.7109*	*1.8475*	7.5670
4 (241)	[b]-1.25	0.00285	*1.3708*	*3.6068*	6.5730	[a]4.167	0.00225	*-0.7152*	*1.8680*	7.5740
5 (242)	[b]-2.49	0.00284	*1.3771*	*3.6235*	6.4710	[d]-1.152	0.00225	*-0.7018*	*1.8328*	6.9380
6 (243)	[a]-4.132	0.00284	*1.3686*	*3.6074*	6.3740	[b]-1.653	0.00224	*-0.7081*	*1.8539*	6.8230
7 (244)	[b]-2.058	0.00283	*1.3757*	*3.6390*	6.2530	[b]-1.235	0.00223	*-0.7117*	*1.8739*	6.7530
8 (245)	[a]-8.197	0.00282	*1.3823*	*3.6689*	6.2370	[b]-2.459	0.00223	*-0.6995*	*1.8501*	6.3150
9 (246)	[a]-8.163	0.00281	*1.3827*	*3.6914*	6.2540	[a]-8.163	0.00223	*-0.7081*	*1.8649*	6.5400
10 (247)	[b]-2.439	0.00280	*1.3854*	*3.7181*	6.2800	[a]-8.13	0.00224	*-0.6976*	*1.7884*	6.7900
11 (248)	[d]9.832	0.00278	*1.3906*	*3.7455*	6.3210	[b]2.429	0.00224	*-0.6944*	*1.8019*	6.6770
12 (249)	[d]-7.554	0.00279	*1.3769*	*3.6846*	6.2910	[b]1.613	0.00223	*-0.6882*	*1.8059*	6.8310
13 (250)	[a]-4.016	0.00278	*1.3710*	*3.6822*	6.4670	[a]-8.032	0.00222	*-0.6793*	*1.8006*	6.8980
14 (251)	[b]-2	0.00277	*1.3752*	*3.7119*	6.5170	[a]8	0.00222	*-0.6832*	*1.8184*	6.9580
15 (252)	[d]6.289	0.00276	*1.3756*	*3.7324*	6.5440	[b]-2.39	0.00223	*-0.6681*	*1.7392*	7.6350
16 (253)	[a]3.968	0.00275	*1.3695*	*3.7289*	6.4790	[b]1.19	0.00224	*-0.6516*	*1.6874*	7.6300
17 (254)	[a]-3.953	0.00274	*1.3756*	*3.7588*	6.5720	[a]3.953	0.00224	*-0.6583*	*1.6722*	7.7690
18 (255)	[d]8.4	0.00273	*1.3801*	*3.7903*	6.6130	[b]3.543	0.00224	*-0.6443*	*1.6485*	8.2340
19 (256)	[d]4.524	0.00272	*1.3835*	*3.8166*	6.6270	[b]-1.176	0.00224	*-0.6327*	*1.6304*	8.1200
20 (257)	[b]-1.563	0.00271	*1.3897*	*3.8472*	6.7370	[b]1.563	0.00223	*-0.6240*	*1.6218*	8.7390
21 (258)	[b]1.167	0.00270	*1.3947*	*3.8772*	6.7910	[b]-1.946	0.00224	*-0.6087*	*1.5943*	8.9730
22 (259)	[b]-1.938	0.00269	*1.3996*	*3.9060*	6.7912	[b]1.55	0.00228	*-0.6090*	*1.5174*	7.9100
23 (260)	[b]-1.931	0.00269	*1.3917*	*3.8754*	6.8780	[b]2.703	0.00228	*-0.6218*	*1.5196*	7.3690
24 (261)	[e]1.935	0.00269	*1.3932*	*3.8995*	6.8270	[e]-1.545	0.00228	*-0.6237*	*1.5162*	7.0010

Note: (*) indicates that Normality for the residual series in all sample periods are rejected as the ratio of Kurtosis and skewness with their respective standard errors are either <-2 or >2; (^{a}) means that the values need to be multiplied by 10^{-9}; (^{b}) by 10^{-8}; (^{c}) by 10^{-18}; (^{d}) by 10^{-19}, (^{e}) by 10^{-4} and (^{f}) by 10^{-20}

Equations (5.6) show that constant correlation is incorporated within the conditional covariance function (h_{12t}). In this model, information flows in both markets is allowed to affect the degree of the co-movement between their returns and is captured by the conditional covariance equations. Since the model restricts the correlation coefficient to be constant, the time variation in the conditional covariance is therefore a consequence of only the time-variation in the conditional variances, and not due to changes in the correlation.

As shown in Table 5.3, the GARCH(1,1) effect in the bivariate GARCH(1,1) system for MAR index (i.e., within the EAFE/MAR portfolio) and US index (i.e., within EAFE/US portfolio) exhibits strong persistence (i.e., taking $a + b$ for MAR and US index) in volatility (i.e., either high volatility or low volatility) of 0.92 and 0.71 respectively. The EAFE, however, shows a relatively milder persistence of 0.57 & 0.48 when included with the MAR and the US index separately in the two portfolios. This persistence in volatility has prolonged effects on the conditional covariance, where the interactions of these volatilities will show a longer time impact on the portfolio.

In the CC-bivariate GARCH(1,1) system, even if the time-variation in the conditional covariance is a consequence of only the time-variation of the conditional variances of the two portfolios, correlations of the assets' returns underlying the two separate portfolios do play a role. Table 5.5 shows the various conditional covariance series generated out of the CC-GARCH(1,1) model for the two portfolios.

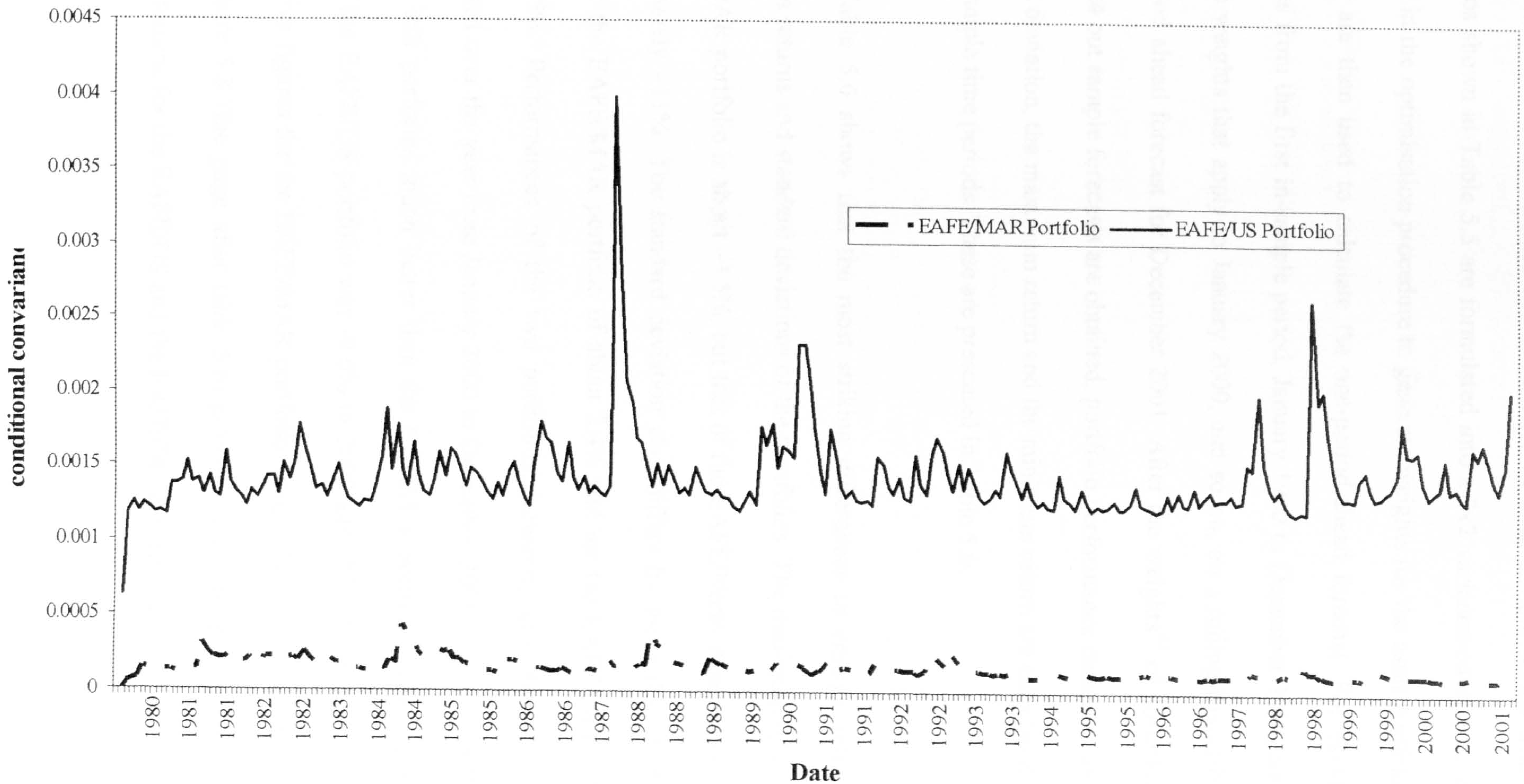
Table 5.5: Conditional variance & covariance series generated by the CC-Bivariate GARCH(1,1) for both the EAFE/US & the EAFE/ Managed Futures portfolios

1) The EAFE/ MAR indexes portfolio				ii) The EAFE/ North America indexes portfolio			
Sample periods (Date sequence)	Cond var EAFE	Cond var Managed Futures	Covariance EAFE/ Managed Futures	Sample periods (Date sequence)	Cond var EAFE	Cond var US	Covariance EAFE/US
1 (Jan-80 to Dec-99)	0.002185289	0.002277127	0.000133979	1 (Jan-80 to Dec-99)	0.002200929	0.002197537	0.0012405625
2 (Jan-80 to Jan-00)	0.002309403	0.001896245	0.000134542	2 (Jan-80 to Jan-00)	0.002399029	0.002379057	0.0013638330
3 (Jan-80 to Feb-00)	0.002869539	0.001833993	0.000152384	3 (Jan-80 to Feb-00)	0.003173261	0.003052257	0.0017732373
4 (Jan-80 to Mar-00)	0.002605163	0.001707598	0.000137738	4 (Jan-80 to Mar-00)	0.002724923	0.00263784	0.0015219786
5 (Jan-80 to Apr-00)	0.002219106	0.001595739	0.000130548	5 (Jan-80 to Apr-00)	0.002210585	0.003259218	0.0015303592
6 (Jan-80 to May-00)	0.00227539	0.001762426	0.000141887	6 (Jan-80 to May-00)	0.00246073	0.003037638	0.0015584694
7 (Jan-80 to Jun-00)	0.002062704	0.001971222	0.000141258	7 (Jan-80 to Jun-00)	0.002100752	0.002609308	0.0013342789
8 (Jan-80 to Jul-00)	0.001948633	0.001785884	0.000134347	8 (Jan-80 to Jul-00)	0.001959259	0.002333287	0.0012204726
9 (Jan-80 to Aug-00)	0.002096344	0.001660894	0.000135997	9 (Jan-80 to Aug-00)	0.002148368	0.002272711	0.0012641008
10 (Jan-80 to Sep-00)	0.002076895	0.001457067	0.00012537	10 (Jan-80 to Sep-00)	0.002102246	0.002433394	0.0012964251
11 (Jan-80 to Oct-00)	0.002510082	0.001276791	0.000130209	11 (Jan-80 to Oct-00)	0.002815959	0.002362627	0.0014783650
12 (Jan-80 to Nov-00)	0.002177459	0.001280282	0.000116056	12 (Jan-80 to Nov-00)	0.002210355	0.00225244	0.0012784833
13 (Jan-80 to Dec-00)	0.002040635	0.001938214	0.000133864	13 (Jan-80 to Dec-00)	0.002030816	0.002572721	0.0013106355
14 (Jan-80 to Jan-01)	0.002026186	0.001830227	0.000129489	14 (Jan-80 to Jan-01)	0.001945418	0.002408362	0.0012418849
15 (Jan-80 to Feb-01)	0.001957168	0.00154601	0.000111832	15 (Jan-80 to Feb-01)	0.001940899	0.002269474	0.0012157836
16(Jan-80 to Mar-01)	0.002446794	0.001373051	0.000108508	16(Jan-80 to Mar-01)	0.002649936	0.00283941	0.0015942073
17 (Jan-80 to Apr-01)	0.002490047	0.001562647	0.000110432	17 (Jan-80 to Apr-01)	0.002512868	0.002829581	0.0015578785
18 (Jan-80 to May-01	0.002411539	0.001534467	0.000107918	18 (Jan-80 to May-01	0.002552701	0.003075812	0.0016357318
19 (Jan-80 to Jun-01)	0.002308501	0.00133785	0.0000993	19 (Jan-80 to Jun-01)	0.00244184	0.002643389	0.0014832708
20 (Jan-80 to Jul-01)	0.002210924	0.001190082	0.0000945	20 (Jan-80 to Jul-01)	0.002277099	0.002389702	0.0013631519
21 (Jan-80 to Aug-01)	0.002132438	0.001214647	0.0000964	21 (Jan-80 to Aug-01)	0.002174878	0.002311382	0.0013158657
22 (Jan-80 to Sep-01)	0.002229388	0.001151396	0.000102536	22 (Jan-80 to Sep-01)	0.002292675	0.002847649	0.0015149401
23 (Jan-80 to Oct-01)	0.00331018	0.001158554	0.000130891	23 (Jan-80 to Oct-01)	0.003639268	0.003199154	0.0020242867
24 (Jan-80 to Nov-01)	0.002743138	0.001599292	0.000130682	24 (Jan-80 to Nov-01)	0.002764796	0.002859488	0.0016722584

Using Table 5.5, the average value (of the 24 in-sample periods) of conditional variance and conditional covariance can easily be calculated. The average conditional variance for the MAR and the EAFE index (within the EAFE/MAR Indexes portfolio) are 0.0016 and 0.0023 respectively, while the average conditional covariance of the portfolio is 0.000124. In the case of the EAFE/US Indexes portfolio, the average conditional variance for the EAFE and the US index are 0.0024 and 0.0026 respectively, while the average conditional covariance of the portfolio is 0.00145. For the EAFE/MAR Indexes portfolio, the average conditional variance of MAR index is lower than the EAFE index by about 30% (0.0016 vs 0.023), while for the EAFE/US Indexes portfolio, the average conditional variance values are nearly the same (0.0024 vs 0.0026).

The values of conditional variances underlying the market indexes naturally affect the conditional covariance of the portfolio. However, as conditional covariance is now a function of constant correlation, the differences in the correlations of returns of the market indexes underlying the portfolio, as observed from Table 5.3, naturally will also contribute to the difference in the conditional covariance. It is therefore not surprising that average conditional covariance for EAFE/MAR Indexes portfolio (i.e., 0.000124) is lower than the EAFE/US Indexes portfolio (i.e., 0.00145) by about 90% because as observed from Table 5.5, the correlation between the MAR and the EAFE Index is only about 0.07, while that of the US and the EAFE Index is significantly (1% level) higher at 0.57. Figure 5.2 provides a graphical comparison of the conditional covariance of the two portfolios.

Figure 5.2: Comparison of monthly conditional covariance: 1980 to 2001 EAFE/MAR portfolio vs EAFE/US portfolio



The conditional variance and covariance of each sample period from the two portfolios shown in Table 5.5 are formulated into a 2x2 variance-covariance matrix to be used in the optimisation procedure to generate weights for the asset portfolio. These weights are then used to calculate the one-period-ahead forecast. For example, the estimates from the first in-sample period, January 1980 to December 1999, are used to generate weights that apply to January 2000, and so on, on a rolling basis till the last one period ahead forecast for December 2001. After the weights[22] of portfolio returns for the 24 out sample forecasts are obtained, portfolio performance measures such as the standard deviation, the maximum return and the minimum return are calculated over the 24 out sample time periods. These are presented in Table 5.6.

Table 5.6 shows that the most striking differences to emerge relate to the minimum returns and standard deviations of the portfolios. The minimum return for the EAFE/MAR portfolio is about –3.5%, but that of the EAFE/North America portfolio is approximately –11%. The standard deviation also differs by more than 100%, with value for the EAFE/MAR portfolio of about 2.4% and for the EAFE/US portfolio of about 5.5%. Performances of the two portfolios, however, are observed to have deteriorated over the year from January 2000 to December 2001. But, the EAFE/MAR portfolio still performs much better than the EAFE/US portfolio. The compounded return of the EAFE/US portfolio was -9.6% in 2000 and -17.72% in 2001, while the comparative figures for the EAFE/MAR portfolio were 3.44% in 2000 and -7.97% in 2001. Figure 5.3 (the page after table 5.6) provides a graphical comparison of the portfolio returns for the EAFE/US and the EAFE/MAR portfolio for the 24 out-sample periods.

[22] Microsoft EXCEL solver is used to set the algorithm for optimisation that derives the weights of the portfolios.

Table 5.6.: Descriptive statistics of the out sample monthly portfolio returns from January 2000 to December 2001: Comparison of EAFE/US portfolio and EAFE/MAR portfolio

	EAFE/US portfolio	EAFE/MAR portfolio
Portfolio returns		
Average monthly returns	-1.082%	-0.178%
Maximum monthly returns	10.794%	4.448%
Minimum monthly returns	-11.131%	-3.474%
Portfolio volatility		
Standard deviation	5.457%	2.386%
Compounded portfolio returns		
2000	-9.580%	3.441%
2001	-17.723%	-7.974%

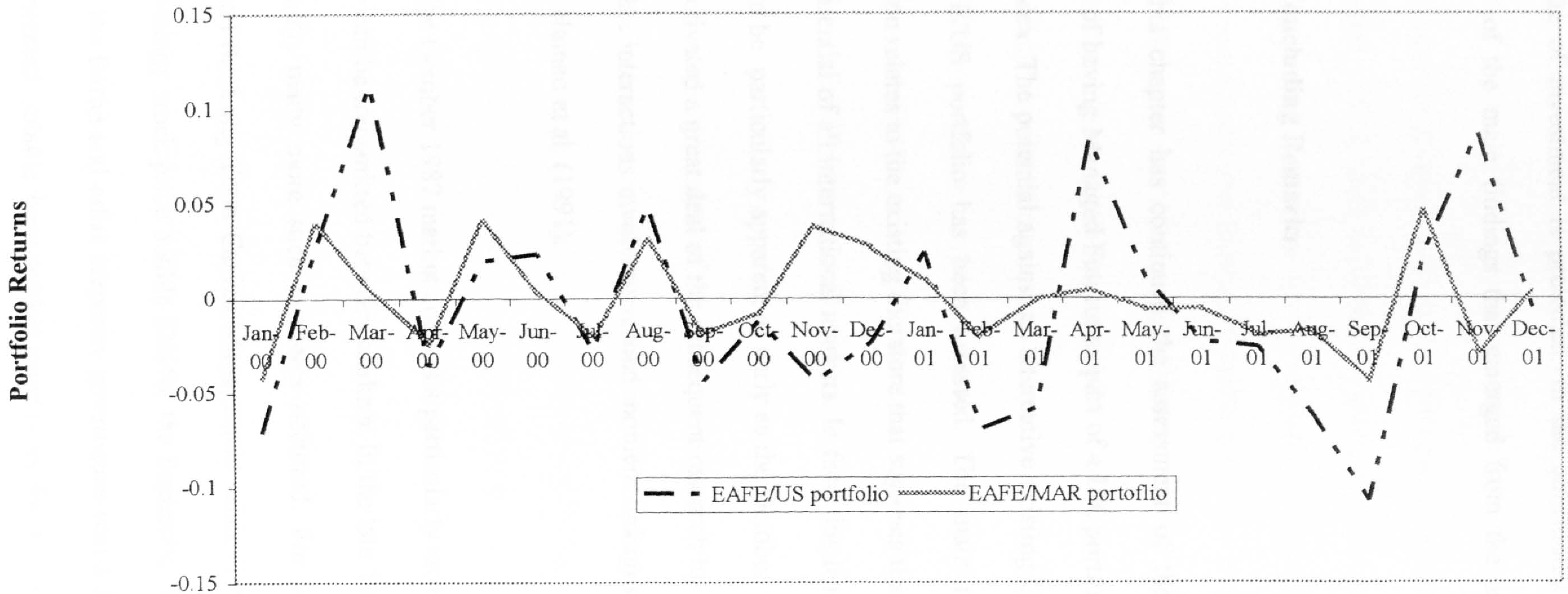
Note: The critical values for testing the difference in means between the two portfolios are 2.07 (5% significant level), 2.82 (1% significant level) and 1.72 (10% significant level). As the t-statistics (p value) is about 0.586 (0.563), the null hypothesis of no difference between the monthly return series of the two portfolios cannot be rejected. The monthly returns series of the EAFE/US portfolio and the EAFE/MAR portfolio are therefore not significantly different from one another.

It is perhaps not surprising that the average returns are negative for both portfolios. The 2000 to 2001 period was one of the most volatile in recent financial history. All the major stock markets around the world saw large falls in equity prices and hence significant and widespread portfolio losses[23] are to be expected.

The empirical research in this chapter has provided evidence suggesting that having Managed Futures in conjunction with an existing EAFE index portfolio for the UK investor would have reduced portfolio losses by more than 2 times compared to that

[23]An annual survey by PriceWaterhouseCoopers, as referenced in the Economist March 2002, shows that UK fund managers' revenue fell on average by 5.5% in 2001. As fund management fees are linked with the value of the assets under management, this is yet another consequence of the weakening of stock market values over the past two years. The article also reported that the UK fund management firm, Schroders, an investment group also reported this year that, for the first time in nearly 200 years of trading, it had suffered losses.

Figure 5.3: Comparison of out sample returns: Jan 2000 to Dec 2001
EAFE/US portfolio verus EAFE/MAR portfolio



	1/00	2/00	3/00	4/00	5/00	6/00	7/00	8/00	9/00	10/00	11/00	12/00	1/01	2/01	3/01	4/01	5/01	6/01	7/01	8/01	9/01	10/01	11/01	12/01
EAFE/US portfolio	-0.07	0.026	0.113	-0.04	0.02	0.024	-0.03	0.048	-0.04	-0.01	-0.04	-0.02	0.024	-0.07	-0.06	0.084	0.011	-0.02	-0.03	-0.06	-0.11	0.023	0.087	-0.01
EAFE/MAR portoflio	-0.04	0.039	0.005	-0.02	0.041	0.004	-0.02	0.03	-0.02	-0.01	0.038	0.027	0.009	-0.02	-0	0.004	-0.01	-0.01	-0.02	-0.02	-0.04	0.046	-0.03	0.003

Date

of the EAFE/US portfolio. This is beneficial to the UK investor as it indicates that the time value of investment is protected. In the concluding section of this chapter, a summary of the main findings that emerged from the analysis in this chapter are provided.

5.5 Concluding Remarks

This chapter has continued the assessment of the potential benefits to UK investors of having Managed Futures as part of a UK portfolio consisting mainly of the EAFE index. The potential against an alternative existing UK investment consisting of the EAFE/US portfolio has been assessed. The main reason for conducting this comparison relates to the existing literature that suggests that the US market remains the most influential of all international markets. In fact, this feature of the US stock market appears to be particularly apparent as early as the October 1987 market crash, an event which motivated a great deal of the subsequent research by academics and practitioners into market interactions involving second moment linkages. Similar evidence was also found by Hamao et al. (1991).

The October 1987 market crash is a particularly striking example of how market volatility can be transmitted between markets. In the late 1990's to the beginning of the 21st century, many more such incidents occurred. For example, the Russian Bond default and the Long Term Capital Management crisis (1998), the collapse of internet and technology stock price bubble (2000), the September 11th events (2001) and most recently, the Enron and other corporate governance scandals (2002). These events may have generated volatile bear market conditions for the world's stock markets. For example, the two main stock market indexes in the US, the Dow Jones Industrial index and the NASDAQ, broke record percentage losses, especially the latter index, which collapsed by more than 70% from its peak in early 2000.

It is in circumstances such as these that investors tend to turn to alternative types of investment. The growth in Managed Futures trading and other forms of alternative investment suggest that these are increasingly becoming a significant element of investors overall portfolios. Hence, determining whether investors would have benefited from including this asset class within their portfolios is likely to be of interest to investors, fund managers and regulators alike. In order to determine the incremental benefits of including Managed Futures within an already diversified portfolio, the empirical research applied a portfolio optimisation algorithm, calibrated on in-sample data and controlling for time-varying variance, using the constant-correlation-bivariate GARCH(1,1) model and then tested it on out-sample data.

The empirical research provides findings on the effect of the conditional covariance in determining portfolio returns. The CC-Bivariate GARCH(1,1) model restricts the correlation coefficient to a constant and the time variation in the conditional covariance is therefore a consequence of only the time-variation in the conditional variances, and not due to changes in the correlation. The main reason for the choice of this model is that it highlights the fact from previous research, such as Edward and Liew (1999) and Edwards and Caglayan (2001) that has consistently shown Managed Futures to be lowly or negatively correlated with other traditional investments such as stocks and bonds. The empirical research also provides evidence suggesting that the low or negative correlations of returns of the market indexes, that include Managed Futures, which are used in this chapter, also appear to be significantly constant over times. This observation is incorporated in model selection.

The empirical findings also reveal that the correlations of returns of the underlying assets within the portfolio, indeed, appear to play a role in determining the portfolio's conditional covariance. It is also quite clear from the results in Appendix 5.10B, which presents the coefficient estimates of the VAR, shows that the returns of the Managed Futures and the EAFE indexes do not show any strong significant relationships. However, for the case of the returns of the EAFE and the US indexes (Appendix 5.10A) it does appear to show some significant relationship. What is also obvious is that the statistically significant coefficients on the US index imply that it is leading the EAFE index. Though the reverse might not be the case, there is evidence that the EAFE & US index correlation is significantly stronger at 0.57 (see Table 5.3). However, this only leads to higher conditional covariance for the EAFE/US portfolio which does not add value to portfolio returns during volatile times.

Nevertheless, as far as the research question is concerned, i.e., to assess the potential of using Managed Futures as part of a UK investor's portfolio, the empirical evidence appears to be in support of the use of Managed Futures within a UK portfolio. This is true when compared with the EAFE/US portfolio. As far as this is concerned, it is best to consider a portfolio where the underlying market return correlation and the portfolio's conditional covariance are the smallest. Using the CC-Bivariate GARCH(1,1) model of conditional volatility, the empirical study has shown that using Managed Futures with the EAFE market index within a portfolio provides a better cushion for the portfolio from shocks – especially, it seems, during particularly volatile market periods.

Appendix 5.1: Procedures used to determine the appropriate lags for the Auto-Regression function for the 3 market indexes

The following explains briefly the steps in which we go about finding the lags to model the GARCH (1,1) equation and to explain the conditional volatility.

1. AR(1), AR(2) and AR(3) processes are calculated for the 3 market indexes: MSCI US Index, MSCI EAFE index and the MAR (i.e., Managed Futures) index.

2. The residuals from AR(1), AR(2) and AR(3) are then used to estimate the GARCH (1,1) process.

3. The estimation result of AR(1)-GARCH (1,1), AR(2)-GARCH (1,1) and AR(3)-GARCH (1,1) for the 24 sample out-of-sample rolling for the market indexes are then compiled. Appendix 5.3(A to C), 5.4(A to C) and 5.5(A to C) give the details.

4. The evaluation of the coefficient estimates and the maximum likelihood values of the GARCH (1,1) process using the different lags for the Auto-Regression functions. The selection of the appropriate lag to be based upon, not only the maximum likelihood values, but also the extent in which the estimates fit the model well, judging on the value of the standard errors.

AR(3)-GARCH(1,1)[1] is selected to model the conditional volatility of the three market indexes. In terms of comparing the maximum likelihood estimates, Appendices 5.1A to 5.1C do not appear to show clearly that AR(3)-GARCH(1,1) is the best choice. However, reviewing results produced in Appendices 5.3 to 5.5 shows that AR(3)-GARCH(1,1) appears to be a better fit for the 3 market indexes. Some observations from Appendices 5.3 to 5.5 are as follows:

1. Appendix 5.3A clearly shows that the specification for the MSCI US index (AR (1)), is a bit problematic as it has a rather large standard error

2. From Appendix 5.5, it is also observed that even though the maximum likelihood estimates for AR(2) of Managed Futures tend to be higher among all other AR lags, it, however, doesn't comply with stationarity condition, $\alpha + \beta < 1$. The same is also applied to AR(1). In fact, the average values of $\alpha + \beta$ for AR(1) and AR(2) appear to be 1.006, while that of AR(3) is only 0.9361. Pursuing the use of AR(2) or AR(1) is therefore likely to distort our interpretation of the results.

Persistent misspecifications of the parameters were observed after running the iterations for a considerable number of times, particularly for AR(2). It is decided to use AR(3) in the end, since it specifies the GARCH(1,1) more precisely and accurately. However, choosing AR(3) over AR(1) or AR(2) will make a difference to the outcome[2].

Using different lags to generate the Auto-Regression naturally affects the residual (or error terms). Regarding this point, see footnote 7 for a brief discussion.

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[1] Refer to Appendix 5.2 for the parameter estimates of the Auto-Regression for the 3 market indexes.

[2] Appendix 5.1A and Appendix 5.1B show that this result will make a difference between AR(1) and AR(3), and between AR(2) and AR(3) for the MSCI EAFE index and the MSCI US index respectively; Appendix 5.1C, however, shows that results will make a difference choosing between AR(2) and AR(3), but not choosing between AR(1) and AR(3) for the MAR index.

Appendix 5.1A : Likelihood ratio (LR) test for MSCI EAFE Index, on qualifying using either AR(1), AR(2) or AR(3) for generating univariate GARCH(1,1)

	MSCI EAFE index								
	Maximum likelihood Estimates of GARCH(1,1)			LR Test Statistics and P Values					
Sample Periods	**Using Residual Series AR(1)**	**Using Residual Series AR(2)**	**Using Residual Series AR(3)**	**Test values for AR(1) & AR(2)**	**P-Values**	**Test values for AR(1) & AR(3)**	***P-Values***	**Test values for AR(2) & AR(3)**	***P-Values*****
1	606.98	606.38	604.16	1.2076	0.2718	5.6469	*0.0594**	4.4393	*0.0351*
2	608.31	607.66	605.15	1.2974	0.2547	6.3207	*0.0424***	5.0233	*0.0250*
3	610.80	610.17	607.69	1.2559	0.2624	6.2127	*0.0448***	4.9568	*0.0260*
4	613.77	613.13	610.67	1.2896	0.2561	6.2026	*0.045***	4.9131	*0.0267*
5	616.28	615.63	613.15	1.2970	0.2548	6.2615	*0.0437***	4.9645	*0.0259*
6	619.29	618.65	616.15	1.2822	0.2575	6.2766	*0.0434***	4.9944	*0.0254*
7	622.35	621.71	619.43	1.2729	0.2592	5.8303	*0.0542**	4.5574	*0.0328*
8	624.93	624.29	622.01	1.2847	0.2570	5.8454	*0.0538**	4.5607	*0.0327*
9	627.78	627.16	624.88	1.2454	0.2644	5.8038	*0.0549**	4.5584	*0.0328*
10	629.39	628.72	626.27	1.3242	0.2498	6.2323	*0.0443***	4.9081	*0.0267*
11	632.33	631.68	629.27	1.2869	0.2566	6.1110	*0.0471***	4.8241	*0.0281*
12	635.25	634.60	632.19	1.3002	0.2542	6.1276	*0.0467***	4.8273	*0.0280*
13	638.17	637.52	635.07	1.3057	0.2532	6.2058	*0.0449***	4.9001	*0.0269*
14	641.21	640.57	638.32	1.2794	0.2580	5.7860	*0.0554**	4.5066	*0.0338*
15	642.81	642.14	639.79	1.3435	0.2464	6.0405	*0.0488***	4.6970	*0.0302*
16	645.07	644.36	642.00	1.4203	0.2334	6.1427	*0.0464***	4.7225	*0.0298*
17	647.46	646.75	644.33	1.4167	0.2339	6.2552	*0.0438***	4.8385	*0.0278*
18	650.03	649.33	646.94	1.3988	0.2369	6.1870	*0.0453***	4.7882	*0.0287*
19	652.73	652.01	649.60	1.4395	0.2302	6.2647	*0.0436***	4.8252	*0.0280*
20	655.48	654.75	652.35	1.4501	0.2285	6.2550	*0.0438***	4.8049	*0.0284*
21	657.96	657.24	654.86	1.4551	0.2277	6.2090	*0.0448***	4.7539	*0.0292*
22	657.70	656.91	654.74	1.5945	0.2067	5.9255	*0.0517**	4.3310	*0.0374*
23	660.30	659.52	657.43	1.5510	0.2130	5.7408	*0.0567**	4.1898	*0.0407*
24	662.90	662.09	660.00	1.6277	0.2020	5.8024	*0.055**	4.1747	*0.0410*

Note: (*) indicates that p values significant at 10% (pertaining to the chi square distribution , with a critical values of 2.706) showing a difference in the statistical outcome when choosing between AR(1) and AR(3) to generate GARCH(1,1). (**) indicates p values significant at 5%, (pertaining to the chi square distribution, with a critical values of 3.841) showing a difference in the statistical outcome when choosing between AR(2) & AR(3) to generate GARCH (1,1).

Appendix 5.1B : Likelihood ratio (LR) test for MSCI US index, on qualifying using either AR(1), AR(2) or AR(3) for generating univariate GARCH(1,1)

	MSCI US index								
	Maximum likelihood Estimates of GARCH(1,1)			LR Test Statistics and P Values					
Sample Periods	**Using Residual Series AR(1)**	**Using Residual Series AR(2)**	**Using Residual Series AR(3)**	**Test values for AR(1) & AR(2)**	**P-Values**	**Test values for AR(1) & AR(3)**	***P-Values****	**Test values for AR(2) & AR(3)**	***P-Values*****
1	600.42	598.80	596.32	3.2369	0.0720	8.1906	*0.0167*	4.9537	*0.0260*
2	601.66	600.06	597.57	3.1984	0.0737	8.1779	*0.0168*	4.9795	*0.0256*
3	604.17	603.02	600.53	2.2845	0.1307	7.2705	*0.0264*	4.9860	*0.0256*
4	605.21	604.21	601.63	1.9995	0.1573	7.1607	*0.0279*	5.1612	*0.0231*
5	607.50	606.49	603.91	2.0118	0.1561	7.1802	*0.0276*	5.1684	*0.0230*
6	610.34	609.38	606.79	1.9302	0.1647	7.1019	*0.0287*	5.1717	*0.0230*
7	613.43	612.33	609.74	2.2068	0.1374	7.3795	*0.0250*	5.1727	*0.0229*
8	616.32	615.11	612.53	2.4362	0.1186	7.5878	*0.0225*	5.1516	*0.0232*
9	618.73	617.52	614.92	2.4313	0.1189	7.6317	*0.0220*	5.2004	*0.0226*
10	621.40	620.19	617.60	2.4252	0.1194	7.6011	*0.0224*	5.1759	*0.0229*
11	624.23	623.03	620.45	2.4075	0.1208	7.5702	*0.0227*	5.1627	*0.0231*
12	626.06	624.87	622.33	2.3850	0.1225	7.4605	*0.0240*	5.0755	*0.0243*
13	628.80	627.60	625.09	2.3947	0.1217	7.4130	*0.0246*	5.0183	*0.0251*
14	631.83	630.58	628.06	2.5115	0.1130	7.5541	*0.0229*	5.0426	*0.0247*
15	633.03	631.83	629.35	2.4062	0.1209	7.3617	*0.0252*	4.9555	*0.0260*
16	635.29	634.04	631.60	2.4906	0.1145	7.3656	*0.0252*	4.8750	*0.0272*
17	637.09	636.00	633.47	2.1890	0.1390	7.2411	*0.0268*	5.0521	*0.0246*
18	639.98	638.90	636.38	2.1673	0.1410	7.2072	*0.0272*	5.0399	*0.0248*
19	642.92	641.82	639.30	2.2124	0.1369	7.2526	*0.0266*	5.0402	*0.0248*
20	645.77	644.62	642.12	2.2858	0.1306	7.2994	*0.0260*	5.0137	*0.0251*
21	646.94	645.82	643.36	2.2581	0.1329	7.1680	*0.0278*	4.9099	*0.0267*
22	648.37	647.03	644.66	2.6770	0.1018	7.4101	*0.0246*	4.7330	*0.0296*
23	651.18	649.88	647.49	2.5984	0.1070	7.3866	*0.0249*	4.7883	*0.0287*
24	653.06	652.03	649.58	2.0673	0.1505	6.9681	*0.0307*	4.9008	*0.0268*

Note: (*) indicates p values significant at 5% (pertaining to the chi square distribution, with a critical values of 3.841), showing a difference in the statistical outcome when choosing between AR(1) and AR(3) to generate GARCH(1,1). (**) indicates p values significant at 5% (pertaining to the chi square distribution, with a critical values of 3.841), showing a difference in the statistical outcome when choosing between AR(2) and AR(3) to generate GARCH(1,1).

Appendix 5.1C : Likelihood ratio (LR) test for the Managed Futures (MAR) index, on qualifying using either AR(1), AR(2) or AR(3) for generating univariate GARCH(1,1)

	MAR index								
	Maximum likelihood Estimates of GARCH(1,1)			LR Test Statistics and P Values					
Sample periods	Using Residual Series AR(1)	Using Residual Series AR(2)	Using Residual Series AR(3)	Test values for AR(1) & AR(2)	*P-Values**	Test values for AR(1) & AR(3)	P-Values	Test values for AR(2) & AR(3)	*P-Values***
1	579.24	585.49	580.27	12.4927	*0.0004*	2.0562	0.3577	10.4365	*0.0012*
2	582.28	588.76	583.31	12.9683	*0.0003*	2.0726	0.3548	10.8957	*0.0010*
3	585.42	592.12	586.40	13.4029	*0.0003*	1.9617	0.3750	11.4412	*0.0007*
4	588.61	595.37	589.50	13.5223	*0.0002*	1.7920	0.4082	11.7303	*0.0006*
5	591.60	598.42	592.51	13.6403	*0.0002*	1.8043	0.4057	11.8359	*0.0006*
6	594.28	601.11	595.23	13.6585	*0.0002*	1.9064	0.3855	11.7520	*0.0006*
7	597.36	604.30	598.23	13.8820	*0.0002*	1.7434	0.4182	12.1386	*0.0005*
8	600.45	607.62	601.36	14.3467	*0.0002*	1.8310	0.4003	12.5156	*0.0004*
9	603.69	611.11	604.58	14.8419	*0.0001*	1.7852	0.4096	13.0568	*0.0003*
10	607.06	614.67	607.90	15.2075	*0.0001*	1.6715	0.4335	13.5360	*0.0002*
11	610.35	618.03	611.14	15.3623	*0.0001*	1.5738	0.4552	13.7885	*0.0002*
12	612.54	619.91	613.37	14.7421	*0.0001*	1.6685	0.4342	13.0737	*0.0003*
13	615.41	623.00	616.31	15.1778	*0.0001*	1.8075	0.4050	13.3702	*0.0003*
14	618.56	626.46	619.48	15.7906	*0.0001*	1.8225	0.4020	13.9681	*0.0002*
15	621.85	629.96	622.68	16.2211	*0.0001*	1.6594	0.4362	14.5617	*0.0001*
16	624.81	633.00	625.65	16.3801	*0.0001*	1.6930	0.4289	14.6871	*0.0001*
17	627.69	635.81	628.53	16.2407	*0.0001*	1.6778	0.4322	14.5629	*0.0001*
18	630.94	639.35	631.76	16.8249	*0.0000*	1.6332	0.4419	15.1917	*0.0001*
19	634.34	642.93	635.07	17.1877	*0.0000*	1.4670	0.4802	15.7207	*0.0001*
20	637.48	646.07	638.14	17.1695	*0.0000*	1.3176	0.5175	15.8519	*0.0001*
21	640.78	649.47	641.36	17.3699	*0.0000*	1.1606	0.5597	16.2093	*0.0001*
22	644.13	652.83	644.56	17.4063	*0.0000*	0.8651	0.6489	16.5412	*0.0000*
23	646.85	655.54	647.41	17.3825	*0.0000*	1.1320	0.5678	16.2505	*0.0001*
24	649.26	657.37	649.75	16.2230	*0.0001*	0.9793	0.6128	15.2436	*0.0001*

Note: (*) indicates p values significant at 1% (pertaining to the chi square distribution, with a critical values of 6.635), showing a difference in the statistical outcome when choosing between AR(1) and AR(2) to generate GARCH(1,1). (**) indicates p values significant at 1% (pertaining to the chi square distribution, with a critical values of 6.635), showing a difference in the statistical outcome when choosing between AR(2) and AR(3) to generate GARCH(1,1).

Appendix 5.2: Conditional means equations and estimates for the 24 in sample periods using AR(3) for the 3 market indexes

Conditional mean equation: $r_t = a_o + a_1 r_{t-1} + a_2 r_{t-2} + a_3 r_{t-3} + \varepsilon_t$

Sample	US				Managed Futures				EAFE			
Periods	a_o	a_1	a_2	a_3	a_o	a_1	a_2	a_3	a_o	a_1	a_2	a_3
1	*0.013019**	*0.15499***	-0.04048	-0.04447	0.017199*	***-*0.11657*	***-0.11584	-0.06523	0.01051*	*0.1225****	*0.00982*	*-0.06487*
2	*0.012854**	*0.14597***	-0.04312	-0.04902	0.017092*	***-*0.11683*	***-0.11681	-0.0633	0.010348*	*0.1134****	*0.0027*	*-0.06866*
3	*0.012866**	*0.14554***	-0.04279	-0.04894	0.017149*	***-*0.11727*	***-0.11661	-0.06263	0.010552*	*0.10444*	*0.00938*	*-0.06406*
4	*0.013318**	*0.14601***	-0.05873	-0.0364	0.017057*	***-*0.11765*	***-0.11593	-0.06284	0.010606*	*0.10586*	*0.00676*	*-0.06206*
5	*0.013049**	*0.13514***	-0.05694	-0.02773	0.016904*	***-*0.11668*	***-0.11636	-0.06178	0.010352*	*0.10484*	*0.00176*	*-0.05341*
6	*0.013118**	*0.1332***	-0.05357	-0.02869	0.017089*	***-*0.11827*	***-0.1176	-0.06134	0.010415*	*0.10344*	*0.00222*	*-0.05225*
7	*0.01314**	*0.13347***	-0.05447	-0.02719	0.016982*	***-*0.11956*	***-0.11666	-0.06062	0.010473*	*0.10378*	*0.00103*	*-0.05176*
8	*0.012978**	*0.13317***	-0.05517	-0.02443	0.016891*	***-*0.11888*	***-0.11772	-0.05983	0.010253*	*0.10271*	*-0.00008*	*-0.04757*
9	*0.013226**	*0.13016***	-0.05395	-0.02411	0.016925*	***-*0.11912*	***-0.118	-0.05944	0.010394*	*0.10015*	*0.0009*	*-0.04716*
10	*0.01309**	*0.12631***	-0.05121	-0.02526	0.01693*	***-*0.11911*	***-0.11803	-0.05947	0.010076*	*0.09571*	*0.0078*	*-0.04977*
11	*0.012966**	*0.12821***	-0.05399	-0.02342	0.016843*	***-*0.1192*	***-0.11829	-0.0589	0.010003*	*0.09752*	*0.00689*	*-0.04869*
12	*0.012662**	*0.13132***	-0.04975	-0.02986	0.017053*	***-*0.12062*	***-0.11816	-0.05835	0.009887*	*0.09792*	*0.0101*	*-0.05011*
13	*0.01243**	*0.13547***	-0.04867	-0.028	0.017148*	***-*0.11868*	***-0.11881	-0.05819	0.009707*	*0.09923*	*0.01049*	*-0.04609*
14	*0.012513**	*0.1348***	-0.05004	-0.02853	0.017121*	***-*0.11905*	***-0.11949	-0.05799	0.009781*	*0.09856*	*0.00993*	*-0.04647*
15	*0.011963**	*0.13275***	-0.04496	-0.01788	0.017151*	***-*0.11923*	***-0.11908	-0.05726	0.009416*	*0.0964*	*0.01381*	*-0.04319*
16	*0.011586**	*0.14175***	-0.04793	-0.01315	0.017263*	***-*0.11895*	***-0.11971	-0.05639	0.00908*	*0.10484****	*0.01127*	*-0.03994*
17	*0.012073**	*0.13445***	-0.05793	-0.01063	0.017138*	***-*0.12035*	***-0.12011	-0.05567	0.009412*	*0.09889*	0.00409	-0.03788
18	*0.011987**	*0.13246***	-0.05608	-0.00869	0.017122*	***-*0.12015*	***-0.12026	-0.0557	0.009153*	*0.0941*	0.00967	-0.03189
19	*0.011918**	*0.13286***	-0.05823	-0.00655	0.017101*	***-*0.12011*	***-0.12001	-0.05585	0.008949*	*0.09743*	0.00528	-0.02662
20	*0.011833**	*0.13355***	-0.05785	-0.00976	0.016958*	***-*0.1199*	***-0.1197	-0.05432	0.008796*	*0.09979*	0.00786	-0.02989
21	*0.01139**	*0.1378***	-0.0556	-0.00966	0.016867*	***-*0.11916*	***-0.11956	-0.05414	0.008509*	*0.10296*	*0.01091*	*-0.02663*
22	*0.010789**	*0.15153***	-0.05326	-0.00651	0.016762*	***-*0.11859*	***-0.11871	-0.05396	0.0078*	*0.11335****	0.01751	-0.01849
23	*0.010953**	*0.14836***	-0.05591	-0.00735	0.016932*	***-*0.11951*	***-0.11964	-0.05526	0.008077*	*0.10492****	*0.01498*	*-0.02089*
24	*0.011396**	*0.15064***	-0.0657	-0.01562	0.016736*	***-*0.12201*	***-0.11861	-0.05419	0.00833*	*0.10804****	*0.00554*	*-0.02393*

Note: (*) indicates parameters significant at 1%; (**) indicates parameters signifcant at 5% & (***) indicates parameters significant at 10%.

Appendix 5.3A: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(1)) for the 24 sample periods: The case of MSCI US market index

*1 (239)***

MLE 600.41

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002080748	0.0011969	1.7383823	0.0834313
β	1.01022E-09	14.392143	7.019E-11	0.999987
α	0.139234833	0.1101916	1.26357	0.20761552

2 (240)

MLE 601.65

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002101872	0.0011905	1.7655624	0.07874616
β	1.35339E-07	78.004977	1.735E-09	0.999987
α	0.142961924	0.112065	1.2757059	0.20329797

3 (241)

MLE 604.16

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002286725	0.0015239	1.5005535	0.13479096
β	8.79573E-06	71.451716	1.231E-07	0.99999987
α	0.138683496	0.1281676	1.0820479	0.28032178

4 (242)

MLE 605.2

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002224498	0.0014505	1.533631	0.12644312
β	4.67045E-06	86.953486	5.371E-08	0.999987
α	0.124276546	0.1230766	1.0097493	0.3136366

5 (243)

MLE 607.49

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.00221866	0.0014915	1.487562	0.13818458
β	8.04242E-06	77.596685	1.036E-07	0.999987
α	0.11733829	0.1236373	0.9490526	0.3435525

6 (244)

MLE 610.34

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0023024	0.0020366	1.130516	0.2593921
β	7.563E-06	103.63345	7.3E-08	0.999987
α	0.0867047	0.1346283	0.64403	0.5201734

7 (245)

MLE 613.43

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0022615	0.0016875	1.340143	0.1814715
β	7.022E-06	90.647262	7.75E-08	0.999987
α	0.1053031	0.1286976	0.818221	0.414046

8 (246)

MLE 616.32

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0021706	0.0013871	1.564779	0.1189579
β	4.265E-06	86.040292	4.96E-08	0.999987
α	0.1183984	0.1190952	0.99415	0.3211555

9 (247)

MLE 618.73

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0021509	0.0013457	1.598372	0.1112814
β	1.909E-08	60.397834	3.16E-10	0.999987
α	0.1194776	0.1166146	1.02455	0.3066112

10 (248)

MLE 621.4

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0021848	0.0014362	1.521193	0.1295334
β	3.936E-06	98.791215	3.98E-08	0.999987
α	0.115242	0.1202555	0.958309	0.3388751

11 (249)

MLE 624.23

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002173	0.001418	1.53212	0.1268153
β	9.47E-08	42.369	2.24E-09	0.999987
α	0.114889	0.119596	0.96065	0.337699

12 (250)

MLE 626.05

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002231	0.001525	1.462737	0.1448532
β	5.56E-06	92.05754	6.04E-08	0.999987
α	0.114524	0.125531	0.912315	0.3625222

13 (251)

MLE 628.79

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.00223	0.001526	1.461277	0.1452529
β	1.08E-05	68.81541	1.57E-07	0.9999999
α	0.114414	0.125994	0.908092	0.3647446

14 (252)

MLE 631.83

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002175	0.001425	1.52595	0.1283445
β	3.94E-07	48.53345	8.12E-09	0.999987
α	0.114376	0.120836	0.946546	0.3448264

15 (253)

MLE 633.03

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002237	0.001534	1.458047	0.1461403
β	8.27E-06	80.70214	1.03E-07	0.999987
α	0.113922	0.126406	0.901239	0.3683686

Appendix 5.3A (Con't)

16 (254)
MLE 635.28

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002239025	0.0015397	1.4542155	0.14719854
β	1.27007E-05	64.944071	1.956E-07	0.99999987
α	0.113941498	0.1276024	0.8929416	0.37278663

17 (255)
MLE 637.09

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002218129	0.0014915	1.4871471	0.13829403
β	6.20965E-06	80.912448	7.675E-08	0.999987
α	0.113639801	0.1243643	0.9137657	0.36176086

18 (256)
MLE 639.98

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002215145	0.0014874	1.4892462	0.13774093
β	6.49871E-06	78.744622	8.253E-08	0.999987
α	0.113278353	0.1239631	0.9138073	0.36173907

19 (257)
MLE 642.92

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002235101	0.0015147	1.4756493	0.14135428
β	8.96647E-06	71.253162	1.258E-07	0.99999987
α	0.114013859	0.1257541	0.9066411	0.36550979

20 (258)
MLE 645.76

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002233683	0.0015097	1.4795454	0.14031148
β	1.05861E-05	67.993065	1.557E-07	0.99999987
α	0.114107251	0.1258727	0.9065288	0.36556905

21 (259)
MLE 646.94

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0022807	0.0018178	1.254664	0.2108265
β	1.014E-05	86.623272	1.17E-07	0.999987
α	0.0951741	0.1334886	0.712976	0.4765564

22 (260)
MLE 648.36

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002285	0.0017972	1.271416	0.2048167
β	4.785E-06	109.8446	4.36E-08	0.999987
α	0.0976142	0.1344499	0.726027	0.4685329

23 (261)
MLE 651.18

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.002242	0.0015185	1.476483	0.1411306
β	5.324E-06	90.648024	5.87E-08	0.999987
α	0.1136548	0.1269792	0.895066	0.3716521

24 (262)
MLE 653.05

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0022833	0.0017872	1.277566	0.2026421
β	9.229E-06	82.064361	1.12E-07	0.999987
α	0.0971584	0.1328132	0.731542	0.4651648

** This indicates the No. of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.3B: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(2)) for the 24 sample periods: The case of MSCI US market index

*1 (238)***

MLE 598.79

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003434	0.0002379	1.4435521	0.1501745
β	0.8080582	0.06788	11.904216	5.773E-26
α	0.052211	0.0945412	0.552257	0.5812884

2 (239)

MLE 600.05

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003298	0.0002185	1.5092421	0.1325578
β	0.8175301	0.061476	13.298352	1.418E-30
α	0.0505177	0.0929724	0.543362	0.587387

3 (240)

MLE 603.02

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000326	0.0002131	1.5300306	0.1273316
β	0.8200127	0.0598328	13.705079	6.187E-32
α	0.0487474	0.0916927	0.5316387	0.5954701

4 (241)

MLE 604.2

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003062	0.0001916	1.5981851	0.111323
β	0.8305456	0.0535887	15.498521	5.712E-38
α	0.0485644	0.0900478	0.5393177	0.5901697

5 (242)

MLE 606.49

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003042	0.0001887	1.6121632	0.1082461
β	0.8310303	0.0528844	15.714079	1.072E-38
α	0.0492152	0.0891864	0.5518246	0.5815841

6 (243)

MLE 609.37

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003037	0.0001876	1.6188992	0.1067878
β	0.8323364	0.052317	15.909488	2.355E-39
α	0.0473471	0.0881427	0.5371638	0.5916542

7 (244)

MLE 612.32

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003076	0.000192	1.6020327	0.1104692
β	0.8309977	0.0533599	15.573454	3.193E-38
α	0.0462311	0.0879914	0.5254054	0.5997885

8 (245)

MLE 615.1

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003137	0.0001988	1.5781586	0.1158518
β	0.8279426	0.0552101	14.996225	2.818E-36
α	0.0462866	0.0884741	0.5231655	0.6013438

9 (246)

MLE 617.51

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003062	0.0001907	1.6057372	0.1096521
β	0.831803	0.0529454	15.710589	1.102E-38
α	0.0457395	0.0872189	0.5244223	0.6004709

10 (247)

MLE 620.18

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003095	0.000194	1.5951998	0.111989
β	0.8299923	0.05389	15.401608	1.212E-37
α	0.0458845	0.0871981	0.526209	0.5992309

11 (248)

MLE 623.03

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003162	0.0002018	1.5671241	0.1184087
β	0.8263857	0.0560883	14.733645	2.161E-35
α	0.0461679	0.0879314	0.5250448	0.6000387

12 (249)

MLE 624.86

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003164	0.0002003	1.579582	0.1155252
β	0.8272597	0.0554663	14.91465	5.307E-36
α	0.0461823	0.0889717	0.5190666	0.6041946

13 (250)

MLE 627.59

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003253	0.0002104	1.5462659	0.1233635
β	0.8227729	0.0582828	14.116915	2.568E-33
α	0.0465367	0.0902549	0.5156138	0.6066008

14 (251)

MLE 630.57

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003281	0.0002142	1.5316511	0.1269311
β	0.821035	0.0594311	13.814915	2.65E-32
α	0.0464038	0.0900894	0.5150865	0.6069686

15 (252)

MLE 631.82

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003196	0.0002011	1.5895784	0.1132518
β	0.8275076	0.055177	14.997323	2.794E-36
α	0.0453034	0.0897888	0.5045559	0.6143357

Appendix 5.3B (Con't)

16 (253)

MLE 634.04

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003295	0.0002118	1.555859	0.1210648
β	0.8226583	0.0581069	14.157659	1.874E-33
α	0.046366	0.0920905	0.5034823	0.615089

17 (254)

MLE 635.99

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003095	0.0001904	1.6261243	0.105241
β	0.8319351	0.0523747	15.884302	2.863E-39
α	0.0462192	0.0893692	0.5171711	0.605515

18 (255)

MLE 638.9

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003121	0.0001926	1.6203216	0.1064818
β	0.8316146	0.0527328	15.770346	6.929E-39
α	0.0447427	0.0888434	0.5036124	0.6149976

19 (256)

MLE 641.81

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003171	0.0001981	1.6004302	0.1108242
β	0.8295954	0.0540964	15.335513	2.024E-37
α	0.04399	0.0889674	0.4944504	0.6214423

20 (257)

MLE 644.62

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003249	0.000207	1.5692359	0.117916
β	0.8256822	0.0565216	14.608253	5.714E-35
α	0.0441678	0.0897214	0.4922776	0.622975

21 (258)

MLE 645.81

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003171	0.000195	1.6263126	0.1052009
β	0.8309713	0.0529127	15.704569	1.154E-38
α	0.0439534	0.0903597	0.4864269	0.6271103

22 (259)

MLE 647.02

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003299	0.0002087	1.5810698	0.1151846
β	0.8233588	0.0569196	14.465303	1.73E-34
α	0.0481414	0.09402	0.5120338	0.6091002

23 (260)

MLE 649.88

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003251	0.0002027	1.6038325	0.1100716
β	0.8271269	0.0549329	15.057051	1.758E-36
α	0.0455836	0.0924577	0.4930213	0.6224502

24 (261)

MLE 652.02

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003133	0.0001906	1.643642	0.101565
β	0.8323897	0.0518271	16.060903	7.277E-40
α	0.0456065	0.0914431	0.4987422	0.6184197

** This indicates the No. of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.3C: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(3)) for the 24 sample periods: The case of MSCI US market index

*1 (237)***

MLE 596.31

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003786	0.000243	1.5581073	0.1192077
β	0.7925795	0.0711511	11.13939	1.736E-23
α	0.0532311	0.0984561	0.5406579	0.5892469

2 (238)

MLE 597.56

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003682	0.0002277	1.616948	0.1058895
β	0.8008892	0.0656918	12.191609	6.6E-27
α	0.0515264	0.0973315	0.5293907	0.5970258

3 (239)

MLE 600.53

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003612	0.0002194	1.6464254	0.0996762
β	0.8052011	0.063138	12.753031	9.248E-29
α	0.0491444	0.0957767	0.5131147	0.6083451

4 (240)

MLE 601.62

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003659	0.0002262	1.6176871	0.1057301
β	0.8038391	0.0643683	12.48812	6.961E-28
α	0.0509974	0.0966363	0.5277257	0.5981793

5 (241)

MLE 603.9

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003663	0.0002247	1.6298574	0.1031317
β	0.8027316	0.0641383	12.515641	5.647E-28
α	0.0523589	0.0957709	0.5467101	0.585088

6 (242)

MLE 606.79

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003615	0.0002192	1.6491664	0.0991135
β	0.8062934	0.0622565	12.951156	2.034E-29
α	0.049832	0.0941934	0.5290397	0.5972689

7 (243)

MLE 609.74

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003649	0.0002234	1.6331994	0.1024272
β	0.8051419	0.0632526	12.729003	1.111E-28
α	0.0486566	0.0938562	0.5184172	0.6046468

8 (244)

MLE 612.52

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003699	0.0002292	1.613828	0.1065647
β	0.8023773	0.0649555	12.352728	1.947E-27
α	0.048803	0.0941632	0.5182806	0.604742

9 (245)

MLE 614.91

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003674	0.0002265	1.6223689	0.1047244
β	0.8037464	0.0640557	12.547616	4.427E-28
α	0.0486894	0.0933539	0.5215575	0.6024614

10 (246)

MLE 617.59

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003683	0.0002265	1.6256574	0.1040226
β	0.8029714	0.0641876	12.509762	5.905E-28
α	0.0488323	0.0929865	0.5251552	0.5999621

11 (247)

MLE 620.44

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003747	0.0002344	1.5983	0.1099761
β	0.7992689	0.066564	12.00752	2.651E-26
α	0.0492319	0.093662	0.525634	0.59963

12 (248)

MLE 622.32

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003599	0.0002157	1.668191	0.0952778
β	0.8083135	0.061083	13.23304	2.342E-30
α	0.0474106	0.0935258	0.506926	0.6126742

13 (249)

MLE 625.09

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003606	0.0002166	1.665143	0.0958843
β	0.8078648	0.0614723	13.14193	4.713E-30
α	0.0470588	0.0940971	0.500109	0.6174583

14 (250)

MLE 628.05

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003656	0.0002227	1.641877	0.1006155
β	0.8048482	0.063264	12.72206	1.171E-28
α	0.0472538	0.0939902	0.502752	0.6156016

15 (251)

MLE 629.34

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003468	0.0001989	1.743556	0.0812364
β	0.8170864	0.0560458	14.57891	7.174E-35
α	0.0447501	0.0931215	0.480556	0.6312717

Appendix 5.3C (Con't)

16 (252)

MLE 631.6

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003473	0.0001996	1.7405623	0.0817603
β	0.8169609	0.0563808	14.490043	1.428E-34
α	0.0449205	0.0948537	0.4735761	0.6362345

17 (253)

MLE 633.46

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003498	0.0002027	1.7252749	0.0844779
β	0.8152241	0.0570276	14.295265	6.459E-34
α	0.0466871	0.0939636	0.4968639	0.6197417

18 (254)

MLE 636.38

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003479	0.0002003	1.7367772	0.0824265
β	0.8170813	0.0561186	14.55991	8.312E-35
α	0.0447834	0.092916	0.481977	0.6302634

19 (255)

MLE 639.29

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000351	0.0002038	1.721962	0.0850765
β	0.8158777	0.0569648	14.322487	5.231E-34
α	0.0439412	0.0927572	0.4737231	0.6361298

20 (256)

MLE 642.11

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003552	0.0002084	1.7042844	0.088328
β	0.8135912	0.0582923	13.957091	8.838E-33
α	0.0439797	0.0931135	0.4723233	0.637127

21 (257)

MLE 643.36

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003376	0.0001874	1.8012401	0.0716651
β	0.8244023	0.0523374	15.751678	8.009E-39
α	0.0422688	0.0935915	0.4516301	0.651945

22 (258)

MLE 644.66

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003361	0.0001855	1.8117353	0.0700272
β	0.8239207	0.0525103	15.690646	1.286E-38
α	0.0451253	0.0965968	0.4671508	0.6408176

23 (259)

MLE 647.49

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003351	0.0001845	1.8162206	0.0693365
β	0.8259208	0.0517271	15.966897	1.508E-39
α	0.0428246	0.0953139	0.4493007	0.6536219

24 (260)

MLE 649.57

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003355	0.000186	1.8040305	0.0712266
β	0.825549	0.0520116	15.872396	3.139E-39
α	0.0435443	0.0954039	0.4564203	0.6485022

** This indicates the No. of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.4A: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(1)) for the 24 sample periods: The case of MSCI EAFE market index

*1 (239)***

MLE 606.983

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0014885	0.0006062	2.4554956	0.0140691
β	0.2419052	0.29726	0.8137832	0.4165792
α	0.1072507	0.1133191	0.946449	0.3448755

2 (240)

MLE 608.31

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015084	0.0006183	2.4396064	0.0147033
β	0.2372748	0.3031099	0.782801	0.4345189
α	0.1113883	0.1152516	0.9664794	0.3347813

3 (241)

MLE 610.796

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.001521	0.0006245	2.4355261	0.0148702
β	0.2318968	0.3093452	0.7496376	0.4542103
α	0.1106024	0.1149941	0.9618098	0.3371172

4 (242)

MLE 613.771

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015391	0.0006333	2.4303377	0.0150848
β	0.2228993	0.3199827	0.696598	0.4867314
α	0.1081016	0.1145894	0.9433825	0.3464379

5 (243)

MLE 616.28

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015365	0.0006348	2.4203551	0.0155054
β	0.2246029	0.3193678	0.7032737	0.4825697
α	0.1079073	0.1146624	0.9410873	0.3476103

6 (244)

MLE 619.288

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015312	0.0006304	2.4287277	0.0151519
β	0.2246364	0.3183012	0.7057351	0.4810402
α	0.1071763	0.1138779	0.9411511	0.3475777

7 (245)

MLE 622.345

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015237	0.0006202	2.4565851	0.0140265
β	0.2240659	0.3150878	0.7111219	0.4777021
α	0.1084764	0.1134072	0.9565213	0.3397755

8 (246)

MLE 624.932

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.001522	0.0006207	2.4519094	0.01421
β	0.2248257	0.3147243	0.7143576	0.4757032
α	0.1084478	0.1134413	0.9559813	0.3400476

9 (247)

MLE 627.781

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.001518	0.0006172	2.4593137	0.0139203
β	0.2250829	0.3136308	0.7176683	0.4736627
α	0.1082135	0.1128711	0.958735	0.3386611

10 (248)

MLE 629.386

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015394	0.0006388	2.4099604	0.0159543
β	0.2222663	0.323295	0.687503	0.4924324
α	0.1072087	0.1142497	0.9383714	0.3490009

11 (249)

MLE 632.325

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015324	0.0006423	2.3856942	0.01705
β	0.2257581	0.3231342	0.6986512	0.48545
α	0.1030961	0.1128634	0.9134589	0.36192

12 (250)

MLE 635.253

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015352	0.0006399	2.3991046	0.01644
β	0.2219543	0.3253416	0.6822193	0.49576
α	0.1035074	0.1127456	0.9180613	0.35951

13 (251)

MLE 638.172

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015261	0.000632	2.4149185	0.01574
β	0.2233148	0.3214708	0.694666	0.48794
α	0.1043376	0.1124553	0.9278145	0.35444

14 (252)

MLE 641.212

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015147	0.0006209	2.4395665	0.0147
β	0.2248579	0.3163788	0.7107237	0.47795
α	0.1053748	0.1118362	0.9422246	0.34703

15 (253)

MLE 642.81

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015468	0.0006532	2.3680309	0.01788
β	0.2193384	0.3327266	0.6592151	0.51039
α	0.1019908	0.1131846	0.9011009	0.36844

Appendix 5.4A (Cont't)

16 (254)
MLE 645.071

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015377	0.0006475	2.3747722	0.0175598
β	0.2234991	0.326825	0.6838494	0.4947328
α	0.1034605	0.1137936	0.9091943	0.3641635

17 (255)
MLE 647.457

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015467	0.0006496	2.3808875	0.017271
β	0.219577	0.3303251	0.66473	0.5068641
α	0.1042045	0.1138037	0.9156515	0.3607726

18 (256)
MLE 650.033

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015492	0.0006526	2.3737674	0.0176076
β	0.2182044	0.3327766	0.6557083	0.5126425
α	0.1040426	0.1137585	0.9145915	0.3613279

19 (257)
MLE 652.732

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015447	0.0006511	2.3724453	0.0176708
β	0.2195091	0.3315276	0.6621141	0.508536
α	0.1036641	0.1136808	0.9118873	0.3627469

20 (258)
MLE 655.477

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015385	0.0006477	2.3752781	0.0175357
β	0.2211697	0.3291536	0.6719345	0.5022744
α	0.1036164	0.1135537	0.912488	0.3624314

21 (259)
MLE 657.964

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015328	0.0006467	2.3701466	0.017781
β	0.2241613	0.3262754	0.6870309	0.4927294
α	0.1036438	0.1137269	0.9113395	0.3630348

22 (260)
MLE 657.702

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015632	0.0006688	2.3374693	0.0194148
β	0.2235227	0.3310613	0.6751701	0.5002204
α	0.108371	0.1174927	0.9223634	0.3572693

23 (261)
MLE 660.3

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015779	0.0006873	2.295761	0.0216896
β	0.219409	0.3427564	0.6401312	0.5227005
α	0.1033725	0.1163238	0.8886615	0.3750785

24 (262)
MLE 662.901

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0015882	0.0006901	2.301268	0.0213765
β	0.2147431	0.3477061	0.6175993	0.5374275
α	0.1027874	0.1163115	0.8837247	0.3777329

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.4B: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(2)) for the 24 sample periods: The case of MSCI EAFE market index

1 (238) **

MLE 606.37

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000979	0.0006219	1.5742554	0.1154285
β	0.4693846	0.29726	1.5790372	0.1156501
α	0.0961885	0.1133191	0.8488292	0.3968257

2 (239)

MLE 607.66

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010084	0.0006316	1.5965575	0.1103644
β	0.4580835	0.3031099	1.5112783	0.1320386
α	0.1004364	0.1152516	0.8714534	0.3843812

3 (240)

MLE 610.16

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009993	0.0006349	1.5740021	0.115487
β	0.4630663	0.3093452	1.496924	0.1357325
α	0.0989995	0.1149941	0.8609099	0.3901505

4 (241)

MLE 613.12

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010044	0.0006449	1.5575428	0.1193416
β	0.460556	0.3199827	1.4393154	0.1513696
α	0.0967216	0.1145894	0.8440713	0.3994736

5 (242)

MLE 615.63

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010036	0.0006437	1.5590582	0.1189826
β	0.4610801	0.3193678	1.4437277	0.1501251
α	0.0968223	0.1146624	0.8444121	0.3992836

6 (243)

MLE 618.64

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010056	0.0006432	1.5634848	0.117939
β	0.4584473	0.3183012	1.4402939	0.151093
α	0.096427	0.1138779	0.846758	0.397977

7 (244)

MLE 621.7

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010115	0.0006363	1.5896372	0.111917
β	0.4525041	0.3150878	1.4361205	0.152276
α	0.0978172	0.1134072	0.8625311	0.38926

8 (245)

MLE 624.29

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010104	0.0006361	1.588289	0.112221
β	0.453305	0.3147243	1.4403241	0.151084
α	0.0977532	0.1134413	0.8617072	0.389712

9 (246)

MLE 627.15

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010032	0.0006311	1.5895899	0.111927
β	0.455571	0.3136308	1.4525708	0.147655
α	0.0974076	0.1128711	0.8629981	0.389004

10 (247)

MLE 628.72

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010095	0.0006505	1.5518234	0.120705
β	0.4581706	0.323295	1.4171906	0.157729
α	0.0962199	0.1142497	0.842189	0.400524

11 (248)

MLE 631.68

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009912	0.0006512	1.5221004	0.127984
β	0.4675058	0.3231342	1.4467855	0.149267
α	0.0926038	0.1128634	0.8204941	0.412752

12 (249)

MLE 634.6

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009903	0.000647	1.5306788	0.125849
β	0.466286	0.3253416	1.4332195	0.153102
α	0.0926897	0.1127456	0.8221137	0.411832

13 (250)

MLE 637.52

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009915	0.0006397	1.5500224	0.121136
β	0.4635767	0.3214708	1.4420492	0.150598
α	0.0935852	0.1124553	0.8321995	0.406127

14 (251)

MLE 640.57

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009903	0.0006304	1.5709661	0.116191
β	0.4613783	0.3163788	1.4583101	0.146068
α	0.0945755	0.1118362	0.8456615	0.398587

15 (252)

MLE 642.13

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0009932	0.00066	1.504784	0.13238
β	0.4675962	0.3327266	1.4053466	0.161217
α	0.0911507	0.1131846	0.8053275	0.421431

Appendix 5.4B (Cont't)

16 (253)
MLE 644.36

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010074	0.0006555	1.5368614	0.1243273
β	0.4601095	0.326825	1.407816	0.1604849
α	0.0935112	0.1137936	0.8217612	0.4120318

17 (254)
MLE 646.74

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010136	0.000661	1.5334573	0.1251632
β	0.4575088	0.3303251	1.385026	0.167336
α	0.093873	0.1138037	0.8248681	0.410269

18 (255)
MLE 649.33

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010055	0.0006581	1.5278292	0.126555
β	0.4612665	0.3327766	1.3861144	0.1670038
α	0.0934637	0.1137585	0.8215973	0.4121249

19 (256)
MLE 652.01

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010099	0.0006576	1.5357586	0.1245976
β	0.4584848	0.3315276	1.3829461	0.167972
α	0.0935314	0.1136808	0.8227539	0.4114681

20 (257)
MLE 654.75

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010103	0.0006543	1.5441584	0.12255
β	0.4573152	0.3291536	1.389367	0.1660142
α	0.0937499	0.1135537	0.8255995	0.4098547

21 (258)
MLE 657.23

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010082	0.0006507	1.5493835	0.12129
β	0.4583872	0.3262754	1.4049087	0.161347
α	0.0940037	0.1137269	0.8265743	0.409303

22 (259)
MLE 656.9

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010314	0.0006678	1.5445053	0.122466
β	0.4567674	0.3310613	1.3797066	0.168966
α	0.0978149	0.1174927	0.8325187	0.405947

23 (260)
MLE 659.52

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0010146	0.0006807	1.4905533	0.136079
β	0.4670196	0.3427564	1.362541	0.17431
α	0.0931412	0.1163238	0.800706	0.424097

24 (261)
MLE 662.08

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.001031	0.0006931	1.4875586	0.136867
β	0.4596091	0.3477061	1.321832	0.187488
α	0.0927149	0.1163115	0.7971259	0.426169

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.4C: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(3)) for the 24 sample periods: The case of MSCI EAFE market index

*1 (237)***

MLE 604.16

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000829	0.000569863	1.4546872	0.1154285
β	0.5483066	0.198111086	2.7676722	0.0060879
α	0.0837949	0.101791148	0.8232047	0.4112123

2 (238)

MLE 605.15

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002297	0.000112442	2.0427472	0.1103644
β	0.8952321	0.026780563	33.428427	4.466E-92
α	0.0076198	0.090382742	0.0843064	0.9328834

3 (239)

MLE 607.69

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002122	9.44866E-05	2.2456856	0.115487
β	0.9063396	0.022245734	40.742175	1.51E-109
α	0.0044349	0.110234751	0.0402313	0.9679423

4 (240)

MLE 610.67

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002146	9.69161E-05	2.2144958	0.1193416
β	0.9046931	0.022921056	39.469958	1.11E-106
α	0.004576	0.108080196	0.0423386	0.9662641

5 (241)

MLE 613.15

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002227	0.000104775	2.1255101	0.1189826
β	0.8993421	0.024944443	36.053806	1.248E-98
α	0.0062747	0.095983825	0.065372	0.9479325

6 (242)

MLE 616.15

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002262	0.0001091	2.0735465	0.117939
β	0.8966353	0.0261451	34.294576	2.82E-94
α	0.0069637	0.0916789	0.0759576	0.939516

7 (243)

MLE 619.43

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008779	0.0005772	1.5210231	0.111917
β	0.5221211	0.2054785	2.5410015	0.011687
α	0.0878273	0.1025905	0.8560958	0.392802

8 (244)

MLE 622.01

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008748	0.000576	1.5187402	0.112221
β	0.5238977	0.204575	2.5609078	0.011055
α	0.087589	0.1025172	0.8543834	0.393748

9 (245)

MLE 624.88

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008708	0.0005717	1.5232142	0.111927
β	0.5246233	0.2035087	2.5778911	0.010541
α	0.0875812	0.1020933	0.8578544	0.391832

10 (246)

MLE 626.27

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002118	9.247E-05	2.2906647	0.120705
β	0.9061572	0.0219443	41.293518	9E-111
α	0.0040088	0.1140036	0.0351639	0.971978

11 (247)

MLE 629.27

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002183	9.93448E-05	2.197661	0.12798
β	0.9014554	0.023776211	37.91417	4E-103
α	0.0053354	0.101014469	0.052818	0.95792

12 (248)

MLE 632.19

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002221	0.000103724	2.140987	0.12585
β	0.8984206	0.024987497	35.95481	2.2E-98
α	0.0063085	0.09436077	0.066855	0.94675

13 (249)

MLE 635.07

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002401	0.000124497	1.92843	0.12114
β	0.8859996	0.03050082	29.04839	2.3E-80
α	0.0101018	0.080322212	0.125766	0.90002

14 (250)

MLE 638.32

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008396	0.000566369	1.482469	0.11619
β	0.5405532	0.198931999	2.717276	0.00706
α	0.0830513	0.100443954	0.826842	0.40915

15 (251)

MLE 639.79

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002147	9.45988E-05	2.269408	0.13238
β	0.9035968	0.022648152	39.89715	1E-107
α	0.004542	0.10777757	0.042142	0.96642

Appendix 5.4C (Cont't)

16 (252)
MLE 642

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002168	9.53692E-05	2.2731825	0.1243273
β	0.9030525	0.022745852	39.701855	3.3E-107
α	0.0043808	0.110632215	0.0395975	0.9684471

17 (253)
MLE 644.33

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000221	0.000100034	2.2096969	0.1251632
β	0.9002015	0.023933297	37.612931	2.28E-102
α	0.0054502	0.101289331	0.0538087	0.9571325

18 (254)
MLE 646.94

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002156	9.44034E-05	2.2842249	0.126555
β	0.9034279	0.022545927	40.070561	4.83E-108
α	0.0046312	0.107996177	0.0428828	0.9658308

19 (255)
MLE 649.6

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000226	0.000104552	2.161391	0.1245976
β	0.8966225	0.025166482	35.627646	1.373E-97
α	0.0065856	0.094484088	0.0697008	0.9444901

20 (256)
MLE 652.35

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002283	0.000106965	2.1347231	0.12255
β	0.8949139	0.025823943	34.654423	3.533E-95
α	0.0070224	0.092258853	0.076116	0.9393905

21 (257)
MLE 654.86

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002259	0.0001039	2.1738341	0.12129
β	0.8966429	0.0250233	35.832322	4.33E-98
α	0.0064167	0.0956496	0.0670855	0.94657

22 (258)
MLE 654.74

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008245	0.0005909	1.3954984	0.122466
β	0.5627204	0.1965899	2.862407	0.004577
α	0.0809032	0.1035127	0.7815771	0.435237

23 (259)
MLE 657.43

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0007995	0.0006019	1.3282328	0.136079
β	0.5761596	0.1978419	2.9122217	0.003928
α	0.0771425	0.1023189	0.7539414	0.451627

24 (260)
MLE 660

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0008208	0.0006149	1.3347396	0.136867
β	0.5658206	0.2039902	2.7737634	0.005979
α	0.0775904	0.1028324	0.7545326	0.451272

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.5A: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(1)) for the 24 sample periods: The case of Managed Futures index

*1 (239)***

MLE 579.23

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003661	0.0001965	1.8631223	0.062445
β	0.576	0.0519274	11.092409	0
α	0.3948296	0.0539261	7.3216816	0

2 (240)

MLE 582.27

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003623	0.0001957	1.8516677	0.064074
β	0.57461	0.052117	11.025386	0
α	0.3981242	0.0539257	7.3828244	0

3 (241)

MLE 585.42

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003514	0.0001924	1.8267711	0.067734
β	0.577146	0.0513126	11.24764	0
α	0.3983231	0.053376	7.4625826	0

4 (242)

MLE 588.6

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003338	0.0001875	1.7800596	0.075066
β	0.5818583	0.0499028	11.659829	0
α	0.3998223	0.0526123	7.5994074	0

5 (243)

MLE 591.6

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003299	0.000186	1.7737014	0.076112
β	0.5814711	0.0496341	11.715146	0
α	0.4026044	0.052491	7.6699653	0

6 (244)

MLE 594.28

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003322	0.0001869	1.7771482	0.0755438
β	0.5815443	0.04997	11.637865	0
α	0.4009661	0.0526207	7.6199358	0

7 (245)

MLE 597.35

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003093	0.0001808	1.7110294	0.0870757
β	0.5920914	0.0475322	12.456643	0
α	0.3962422	0.051403	7.7085442	0

8 (246)

MLE 600.44

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002934	0.0001756	1.6708165	0.0947579
β	0.5982252	0.0457817	13.066917	0
α	0.3948866	0.0505902	7.805597	0

9 (247)

MLE 603.68

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000268	0.0001674	1.6010702	0.1093615
β	0.6093801	0.0429615	14.184331	0
α	0.3907195	0.0493548	7.9165453	0

10 (248)

MLE 607.06

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002333	0.0001547	1.5077822	0.1316102
β	0.6244908	0.0389784	16.021479	0
α	0.3862499	0.0477338	8.0917504	0

11 (249)

MLE 610.35

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002111	0.0001462	1.443334	0.148926
β	0.6338018	0.0365317	17.349348	0
α	0.3846558	0.0467895	8.220992	0

12 (250)

MLE 612.53

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002713	0.0001655	1.6396024	0.101088
β	0.6070859	0.0432928	14.022779	0
α	0.391502	0.0493294	7.9364838	0

13 (251)

MLE 615.4

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002579	0.0001605	1.6069012	0.108076
β	0.6154139	0.0413185	14.894376	0
α	0.385414	0.0484915	7.9480659	0

14 (252)

MLE 618.56

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002307	0.0001503	1.5351315	0.124751
β	0.6304888	0.0378205	16.670558	0
α	0.3768688	0.0470325	8.0129446	0

15 (253)

MLE 621.85

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002041	0.0001394	1.4645799	0.143036
β	0.6444396	0.0345899	18.63085	0
α	0.3698448	0.0456752	8.0972811	0

Appendix 5.5A (Con't)

16 (254)

MLE 624.8

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002011	0.0001382	1.4545893	0.145783
β	0.6460622	0.0342468	18.864878	0
α	0.3688508	0.0455416	8.0992147	0

17 (255)

MLE 627.68

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001995	0.0001376	1.449913	0.147083
β	0.6468832	0.0341042	18.96787	0
α	0.3687676	0.0454837	8.1076811	0

18 (256)

MLE 630.94

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001737	0.0001259	1.3792554	0.167816
β	0.66261	0.0308688	21.465374	0
α	0.3589908	0.0440192	8.1553193	0

19 (257)

MLE 634.33

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001524	0.0001159	1.3150563	0.188491
β	0.6739961	0.0285789	23.583725	0
α	0.3534262	0.0428468	8.2486009	0

20 (258)

MLE 637.48

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001482	0.0001139	1.3015695	0.193064
β	0.6755564	0.0281974	23.958074	0
α	0.3535478	0.0426366	8.292122	0

21 (259)

MLE 640.78

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001352	0.0001075	1.2573672	0.208621
β	0.6824088	0.0268774	25.389693	0
α	0.3505925	0.0418798	8.3714009	0

22 (260)

MLE 644.12

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001229	0.0001014	1.2113581	0.2257581
β	0.6888169	0.0257121	26.789574	0
α	0.3479553	0.041162	8.4533067	0

23 (261)

MLE 646.84

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001321	0.0001057	1.250211	0.2112226
β	0.6845107	0.0265512	25.780765	0
α	0.3489791	0.0416731	8.3742129	0

24 (262)

MLE 649.25

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0001513	0.000114	1.3269203	0.184535
β	0.671432	0.0286978	23.396634	0
α	0.3584247	0.0429328	8.3485125	0

** This indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.5B: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(2)) for the 24 sample periods: The case of Managed Futures index

*1 (238)***

MLE 585.485

Vars	Coeff	Std Error	T-Stat	Signif
ω	1.51218E-05	0.000022315	0.6776518	0.497994
β	0.911114342	0.011519196	79.095304	0
α	0.092552581	0.041112071	2.2512264	0

2 (239)

MLE 588.761

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000013195	2.10559E-05	0.6266652	0.530879
β	0.91278186	0.010977629	83.149276	0
α	0.091293879	0.039711573	2.2989237	0

3 (240)

MLE 592.122

Vars	Coeff	Std Error	T-Stat	Signif
ω	1.08861E-05	1.96434E-05	0.5541861	0.579453
β	0.914576218	0.010412234	87.836699	0
α	0.089976612	0.038198483	2.3555022	0

4 (241)

MLE 595.367

Vars	Coeff	Std Error	T-Stat	Signif
ω	9.5709E-06	1.88545E-05	0.5076189	0.611719
β	0.915447542	0.01011774	90.479451	0
α	0.089447204	0.037389156	2.3923301	0

5 (242)

MLE 598.424

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000009625	1.88302E-05	0.511147	0.609248
β	0.915430667	0.010108072	90.564319	0
α	0.089468049	0.03736569	2.3943904	0

6 (243)

MLE 601.109

Vars	Coeff	Std Error	T-Stat	Signif
ω	1.11043E-05	1.96562E-05	0.5649261	0.572125
β	0.914608912	0.010395089	87.98471	0
α	0.089870286	0.038166115	2.3547141	0

7 (244)

MLE 604.296

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000009982	1.89641E-05	0.526363	0.598638
β	0.915445904	0.010106774	90.577462	0
α	0.089303682	0.037363554	2.3901281	0

8 (245)

MLE 607.622

Vars	Coeff	Std Error	T-Stat	Signif
ω	8.6987E-06	1.81458E-05	0.4793781	0.631669
β	0.916460045	0.009796913	93.545795	0
α	0.088556869	0.036515289	2.4251997	0

9 (246)

MLE 611.109

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000006655	1.69467E-05	0.3927018	0.694539
β	0.917905115	0.009373503	97.925513	0
α	0.087569489	0.035337859	2.4780644	0

10 (247)

MLE 614.668

Vars	Coeff	Std Error	T-Stat	Signif
ω	4.5668E-06	1.57727E-05	0.2895383	0.772172
β	0.919184476	0.009007147	102.05057	0
α	0.086822435	0.034311353	2.5304288	0

11 (248)

MLE 618.032

Vars	Coeff	Std Error
ω	3.6065E-06	1.52293E-05
β	0.919745941	0.008840234
α	0.08654081	0.033845023

12 (249)

MLE 619.909

Vars	Coeff	Std Error
ω	8.7107E-06	1.75276E-05
β	0.917267799	0.00957706
α	0.087483776	0.035850773

13 (250)

MLE 622.995

Vars	Coeff	Std Error
ω	8.4221E-06	1.74258E-05
β	0.917434646	0.009561338
α	0.087396588	0.035836702

14 (251)

MLE 626.46

Vars	Coeff	Std Error
ω	6.7957E-06	1.64308E-05
β	0.918753631	0.009168874
α	0.086378536	0.034717636

15 (252)

MLE 629.963

Vars	Coeff	Std Error
ω	5.0468E-06	1.54781E-05
β	0.919893534	0.008845313
α	0.085664767	0.033797523

Appendix 5.5B (Con't)

16 (253)

MLE 632.996

Vars	Coeff	Std Error	T-Stat	Signif
ω	5.1973E-06	1.55913E-05	0.3333462	0.738875
β	0.919824949	0.008887695	103.49421	0
α	0.085667507	0.033929279	2.5248844	0

17 (254)

MLE 635.808

Vars	Coeff	Std Error	T-Stat	Signif
ω	6.2597E-06	1.60311E-05	0.3904723	0.696184
β	0.919332386	0.009006802	102.0709	0
α	0.085882487	0.034265848	2.5063582	0

18 (255)

MLE 639.354

Vars	Coeff	Std Error	T-Stat	Signif
ω	4.6032E-06	1.50992E-05	0.3048638	0.760471
β	0.920507008	0.008675006	106.11024	0
α	0.085092852	0.033313208	2.5543278	0

19 (256)

MLE 642.93

Vars	Coeff	Std Error	T-Stat	Signif
ω	2.9535E-06	1.42229E-05	0.2076581	0.835495
β	0.921492897	0.008400291	109.69774	0
α	0.084553066	0.032521078	2.5999466	0

20 (257)

MLE 646.067

Vars	Coeff	Std Error	T-Stat	Signif
ω	3.0549E-06	1.42292E-05	0.2146923	0.83001
β	0.921461664	0.008393223	109.78639	0
α	0.084571785	0.032496468	2.6024916	0

21 (258)

MLE 649.469

Vars	Coeff	Std Error	T-Stat	Signif
ω	2.2513E-06	1.38026E-05	0.163107	0.870433
β	0.921899958	0.008266621	111.52077	0
α	0.084376535	0.032131403	2.6259836	0

22 (259)

MLE 652.832

Vars	Coeff	Std Error	T-Stat	Signif
ω	1.5922E-06	1.34701E-05	0.1182025	0.905906
β	0.922193751	0.00817386	112.82231	0
α	0.084307591	0.031859788	2.6462069	0

23 (260)

MLE 655.537

Vars	Coeff	Std Error	T-Stat	Signif
ω	2.9932E-06	1.41237E-05	0.2119275	0.832164
β	0.921537618	0.008369492	110.10676	0
α	0.084502952	0.032423625	2.6062155	0

24 (261)

MLE 657.37

Vars	Coeff	Std Error	T-Stat	Signif
ω	6.8754E-06	0.000015617	0.440251	0.659753
β	0.919306615	0.008920901	103.05088	0
α	0.085943535	0.034103174	2.5201037	0

** This indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.5C: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from AR(3)) for the 24 sample periods: The case of Managed Futures index

*1 (237)***

MLE 580.26

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0004055	0.0001481	2.7373629	0.006193
β	0.6212783	0.0493571	12.587405	0
α	0.2934708	0.0614498	4.7757804	0

2 (238)

MLE 583.31

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000402	0.0001463	2.7483874	0.005989
β	0.6193624	0.0491606	12.598757	0
α	0.2968489	0.0611156	4.8571736	0

3 (239)

MLE 586.4

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003958	0.000144	2.7486787	0.005984
β	0.6191495	0.0486547	12.72539	0
α	0.298954	0.0606759	4.9270616	0

4 (240)

MLE 589.5

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003914	0.000142	2.7572323	0.005829
β	0.6165532	0.0483217	12.759343	0
α	0.3041956	0.0602492	5.0489533	0

5 (241)

MLE 592.5

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003881	0.0001403	2.7667536	0.005662
β	0.6147896	0.0480886	12.784511	0
α	0.3081835	0.0599793	5.1381643	0

6 (242)

MLE 595.23

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003864	0.000139822	2.7632354	0.0057231
β	0.616631	0.047916381	12.868897	0
α	0.3061241	0.060027117	5.0997629	0

7 (243)

MLE 598.22

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.00038	0.0001368	2.7774486	0.0054787
β	0.6177213	0.047091235	13.117542	0
α	0.307094	0.059536817	5.1580514	0

8 (244)

MLE 601.36

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000372	0.000132864	2.8001785	0.0051074
β	0.6187811	0.046174403	13.400955	0
α	0.308691	0.058978546	5.2339538	0

9 (245)

MLE 604.58

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003613	0.000128428	2.8134047	0.004902
β	0.6207661	0.045018775	13.78905	0
α	0.3102432	0.058326572	5.3190721	0

10 (246)

MLE 607.9

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003495	0.000123728	2.8249593	0.0047287
β	0.6210101	0.04389387	14.147991	0
α	0.3152028	0.057604469	5.4718456	0

11 (247)

MLE 611.13

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003415	0.0001205	2.83399	0.004597
β	0.6195672	0.0432395	14.32872	0
α	0.3213366	0.0571404	5.623637	0

12 (248)

MLE 613.37

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003566	0.0001269	2.810092	0.004953
β	0.6194962	0.04486	13.80955	0
α	0.3139017	0.0580192	5.41031	0

13 (249)

MLE 616.31

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003459	0.0001224	2.82547	0.004721
β	0.6265399	0.0433689	14.44674	0
α	0.3082996	0.0574288	5.368381	0

14 (250)

MLE 619.47

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003363	0.0001176	2.858484	0.004257
β	0.630721	0.042039	15.00324	0
α	0.3060967	0.0567666	5.392199	0

15 (251)

MLE 622.68

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003261	0.0001139	2.863625	0.004188
β	0.633103	0.0409857	15.44692	0
α	0.307041	0.0561784	5.465464	0

Appendix 5.5C (Con't)

16 (252)
MLE 625.65

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003207	0.0001123	2.8564399	0.004284
β	0.635102	0.040507	15.678829	0
α	0.3066672	0.0560033	5.4758786	0

17 (253)
MLE 628.52

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003219	0.0001123	2.86693	0.004145
β	0.6327819	0.0406857	15.552916	0
α	0.3094321	0.0559905	5.5265125	0

18 (254)
MLE 631.75

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.000311	0.0001073	2.8967544	0.00377
β	0.6374372	0.0392833	16.22668	0
α	0.3074237	0.0552925	5.5599512	0

19 (255)
MLE 635.07

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0003011	0.0001034	2.9114212	0.003598
β	0.6389061	0.0382757	16.692221	0
α	0.3097886	0.0546719	5.6663252	0

20 (256)
MLE 638.14

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002984	0.0001026	2.9078699	0.003639
β	0.6375731	0.0381496	16.712441	0
α	0.3132064	0.0544922	5.7477346	0

21 (257)
MLE 641.36

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002902	9.92202E-05	2.9246151	0.0034488
β	0.6393497	0.037267295	17.155786	0
α	0.3146117	0.053979018	5.8284064	0

22 (258)
MLE 644.56

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002828	0.000096443	2.9323362	0.0033642
β	0.6405629	0.036512965	17.543436	0
α	0.3165828	0.053516834	5.9155744	0

23 (259)
MLE 647.41

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002819	9.58324E-05	2.9420415	0.0032606
β	0.6420809	0.036332353	17.672429	0
α	0.3145804	0.053530226	5.8766878	0

24 (260)
MLE 649.74

Vars	Coeff	Std Error	T-Stat	Signif
ω	0.0002959	0.000101212	2.923865	0.0034572
β	0.6333926	0.038046883	16.647687	0
α	0.3207192	0.054195576	5.9178107	0

** This indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.6: The stability of the correlation of returns of the MAR index, MSCI EAFE and MSCI US indexes in different blocks of time periods

5.6A): The Jennrich Chi-Square statistics

The Jennrich χ^2 test (Jennrich, 1970) was developed to investigate the equality of two correlation matrices. The statistic is:

$$\chi^2 = \frac{1}{2} tr(Z^2) - diag'(Z) S^{-1} diag(Z)$$

Here, $Z = c^{1/2} R^{-1}(R_1 - R_2)$, in which $R = (n_1 R_1 + n_2 R_2)/(n_1 + n_2)$ and $c = n_1 n_2 /(n_1 + n_2)$, with R_1 and R_2 the correlation matrices to be compared, and n_1 and n_2 the number of observations on which they are based. Furthermore, $S = (\delta_{ij} + r_{ij} r^{ij})$ with δ_{ij} the Kronecker delta, r_{ij} the elements of R, and r^{ij} the elements of R^{-1}. The Jennrich test statistic has $p(p-1)/2$ degrees of freedom, with p the dimension of the correlation matrices. Except for 1998 to 2001, the other time periods used for comparing correlations of returns shown in 5.7B are divided into sixty-one months each. Sixty One Months is long enough to yield reliable results from the testing of the stability of correlation of returns (see for example, Kaplanis, 1988 and Longin & Solnik, 1995).

Appendix 5.6 (con't): The stability of the correlation of returns of the MAR index, MSCI EAFE and MSCI US indexes in different blocks of time periods

5.6B): The correlations of returns across different time periods

Blocks of time periods	Correlations of returns between		
	MAR/EAFE indexes	MAR/US indexes	EAFE/US indexes
1980 to 1985	-0.131	0.099	*0.49***
1986 to 1991	0.063	*0.362***	*0.533***
1992 to 1997	*0.325***	*0.486***	*0.544***
1998 to 2001	-0.112	-0.232	*0.834****

Note: (**) indicates correlation significant at 1%, with critical values = 0.298 for df = 72; while (***) indicates correlation significant at 1%, with critical values = 0.361 for df = 48.

5.6C): Stability of the correlations of returns

Periods Compared		Jennrich Chi-Square
I	II	
1980 to 1985	1986 to 1991	*0.12811**
1986 to 1991	1992 to 1997	*0.1476**
1992 to 1997	1998 to 2001	*1.13548**
1980 to 1985	1992 to 1997	*0.33057**
1980 to 1985	1998 to 2001	*0.79512**
1986 to 1991	1998 to 2001	*1.50014**

Note: (*) indicates that the statistics (chi-square critical value for df=3 is 6.251(10% level), 7.815 (5% level) and 11.341(1% level)) is insignificant and therefore the hypothesis that the correlation matrix is constant over adjacent periods of 61 months and 48 months cannot be rejected.

Appendix 5.7: Procedures used to determine the appropriate orders for the Vector Auto-Regression (VAR) for the EAFE/US and the EAFE/MAR portfolios

The following explains briefly the steps going about finding the 'appropriate' orders to model the CC-bivariate GARCH (1,1) equation and to explain the conditional volatility.

1. VAR(1), VAR(2) and VAR(3) are generated for the EAFE/US indexes and the EAFE/MAR indexes portfolios.

2. Using residuals from 1) are to generate the CC-bivariate GARCH(1,1) models.

3. The parameters specification and the maximum likelihood estimates for the 24 sample periods of the two portfolios mentioned in 2) are compiled. Appendices 5.8A to 5.8C and 5.9A to 5.8B give the details.

4. VAR(1) is chosen for CC-bivariate GARCH (1,1) modelling for the EAFE/US indexes portfolio as VAR(1) provides the highest maximum likelihood values among the three orders. VAR(3) is chosen for the EAFE/MAR indexes portfolio as the other orders of VAR appear to have problems of not complying with the stationarity condition, $\alpha + \beta < 1$, particularly for the MAR index. The average values of $\alpha + \beta$ using VAR(1) and VAR(2) are 1.03 and 1.01 respectively, while that of using VAR(3) is 0.9249 on average.

Using different orders of VAR naturally affect the residual (or error terms) and the patterns of the residual series subsequently. Regarding this point, see footnote 13 for a brief discussion.

Appendix 5.8A: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(1)) for the 24 sample periods: The case of US/EAFE portfolio

*1 (239)***

MLE 1252.86

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011755	0.0006454	1.8212	0.068577
c_{22}	0.0007148	0.0004836	1.47809	0.139383
b_{11}	0.3659509	0.251968	1.4523702	0.14771
b_{22}	0.6103451	0.1476623	4.1333838	4.95E-05
a_{11}	0.1215113	0.0939915	1.292791	0.197332
a_{22}	0.1021933	0.1017226	1.0046272	0.316092
ρ_{12}	0.5640402	0.0358787	15.72074	0

2 (240)

MLE 1252.87

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001173	0.000644	1.82145	0.068539
c_{22}	0.0007148	0.0004824	1.48179	0.138397
b_{11}	0.3666236	0.2508874	1.4613071	0.145245
b_{22}	0.6108622	0.1470227	4.1548834	4.53E-05
a_{11}	0.1220072	0.0937973	1.3007535	0.194596
a_{22}	0.1015935	0.1012718	1.0031758	0.316791
ρ_{12}	0.5639747	0.0358861	15.7157	0

3 (241)

MLE 1256.78

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011905	0.0006452	1.84524	0.065003
c_{22}	0.0007215	0.0004902	1.47177	0.141084
b_{11}	0.3619445	0.2504634	1.4450997	0.14974
b_{22}	0.6114309	0.1477909	4.137136	4.87E-05
a_{11}	0.1268678	0.0940774	1.3485469	0.178759
a_{22}	0.102949	0.1025938	1.0034625	0.316653
ρ_{12}	0.5708375	0.0353346	16.15522	0

4 (242)

MLE 1261.88

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011908	0.0006442	1.84837	0.06454818
c_{22}	0.0007222	0.0004889	1.47716	0.13963247
b_{11}	0.3599443	0.2507008	1.43575	0.152380256
b_{22}	0.6154031	0.1460559	4.21348	3.56615E-05
a_{11}	0.1294449	0.0944275	1.37084	0.171710818
a_{22}	0.0964	0.1016308	0.94853	0.343817314
ρ_{12}	0.5695368	0.0352881	16.1396	0

5 (243)

MLE 1271

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011911	0.0006428	1.85303	0.06387832
c_{22}	0.0007075	0.0004732	1.49519	0.13486555
b_{11}	0.360033	0.2500913	1.43961	0.151287361
b_{22}	0.6257962	0.1391061	4.4987	1.06756E-05
a_{11}	0.127931	0.0935211	1.36794	0.172616559
a_{22}	0.0965973	0.1016297	0.95048	0.342827135
ρ_{12}	0.5701211	0.0352837	16.1582	0

6 (244)

MLE 1277.05

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011922	0.0006449	1.84882	0.06448381
c_{22}	0.0007162	0.0004825	1.48434	0.13771785
b_{11}	0.3584993	0.2522052	1.42146	0.156487056
b_{22}	0.623369	0.1417006	4.3992	1.63723E-05
a_{11}	0.1261701	0.0929885	1.35683	0.176114004
a_{22}	0.0934528	0.1013042	0.9225	0.35719984
ρ_{12}	0.5700233	0.0351375	16.2227	0

7 (245)

MLE 1283.27

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011967	0.0006407	1.86786	0.06178221
c_{22}	0.0007306	0.0004964	1.47184	0.14106376
b_{11}	0.3535409	0.253339	1.395525	0.16415284
b_{22}	0.6164924	0.1465329	4.207195	3.65963E-05
a_{11}	0.1267492	0.0927395	1.366722	0.172996782
a_{22}	0.0926073	0.101573	0.911732	0.362828552
ρ_{12}	0.5698525	0.0350109	16.27645	0

8 (246)

MLE 1289.07

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001197	0.0006374	1.87791	0.06039402
c_{22}	0.0007412	0.0005067	1.46276	0.14353274
b_{11}	0.3532799	0.2519532	1.402165	0.162163471
b_{22}	0.6105281	0.150476	4.057312	6.72559E-05
a_{11}	0.127108	0.0926836	1.371419	0.171530672
a_{22}	0.0932836	0.1018519	0.915874	0.360656018
ρ_{12}	0.5707794	0.0349057	16.35202	0

9 (247)

MLE 1294.69

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011898	0.0006312	1.88489	0.05944408
c_{22}	0.0007382	0.0005012	1.47283	0.14079788
b_{11}	0.3554645	0.249365	1.425479	0.155323615
b_{22}	0.6123423	0.1483125	4.128731	5.04337E-05
a_{11}	0.1268365	0.0919934	1.378757	0.169258688
a_{22}	0.0934993	0.1011721	0.924161	0.356334656
ρ_{12}	0.5720775	0.0347459	16.46459	0

Appendix 5.8A (con't)

10 (248)
MLE 1299.31

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012036	0.0006437	1.86997	0.061488
c_{22}	0.0007432	0.0005034	1.47641	0.139834
b_{11}	0.3540198	0.2521758	1.4038608	0.161658
b_{22}	0.6104985	0.1491288	4.0937671	5.81E-05
a_{11}	0.1281688	0.092923	1.3793014	0.169091
a_{22}	0.0925053	0.100876	0.9170202	0.360056
ρ_{12}	0.5732013	0.0347233	16.5077	0

11 (249)
MLE 1305.3

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011936	0.0006421	1.8588	0.063056
c_{22}	0.0007398	0.0005028	1.47149	0.141158
b_{11}	0.3591335	0.2505317	1.4334852	0.153026
b_{22}	0.6114451	0.1492807	4.0959419	5.76E-05
a_{11}	0.1240409	0.0918261	1.3508242	0.178029
a_{22}	0.0916884	0.1008226	0.9094031	0.364054
ρ_{12}	0.5731147	0.034625	16.55206	0

12 (250)
MLE 1310.32

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012018	0.0006467	1.85832	0.063123
c_{22}	0.0007387	0.000508	1.45413	0.145909
b_{11}	0.3536747	0.255127	1.3862693	0.166957
b_{22}	0.6152977	0.1493714	4.1192484	5.24E-05
a_{11}	0.1236573	0.091829	1.3466035	0.179384
a_{22}	0.0901105	0.1019001	0.8843027	0.377422
ρ_{12}	0.5729386	0.0346816	16.51994	0

13 (251)
MLE 1316.38

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012006	0.0006429	1.86761	0.06181638
c_{22}	0.0007341	0.0005039	1.45671	0.1451955
b_{11}	0.3516344	0.2553931	1.37684	0.169851357
b_{22}	0.6166123	0.1485044	4.15215	4.58527E-05
a_{11}	0.1242582	0.091599	1.35654	0.176205873
a_{22}	0.0896986	0.1016694	0.88226	0.378524103
ρ_{12}	0.573344	0.0345476	16.5958	0

14 (252)
MLE 1322.62

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011961	0.0006323	1.89159	0.05854513
c_{22}	0.0007332	0.0005007	1.46419	0.14314156
b_{11}	0.3505475	0.2525515	1.38802	0.166422295
b_{22}	0.6158684	0.1480727	4.15923	4.45475E-05
a_{11}	0.1256339	0.0910625	1.37964	0.168985408
a_{22}	0.0894775	0.101006	0.88586	0.376581948
ρ_{12}	0.5736983	0.0343848	16.6846	0

15 (253)
MLE 1326.86

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012035	0.0006435	1.87032	0.06143926
c_{22}	0.0007322	0.0005021	1.45835	0.14474452
b_{11}	0.3526269	0.2539168	1.38875	0.166201713
b_{22}	0.6209846	0.1462642	4.24564	3.12219E-05
a_{11}	0.1256831	0.0914581	1.37422	0.170662171
a_{22}	0.0884934	0.1013888	0.87281	0.383641773
ρ_{12}	0.5792536	0.0340022	17.0358	0

16 (254)
MLE 1332.15

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011968	0.000644	1.85833	0.06312167
c_{22}	0.0007272	0.0005016	1.44964	0.1471588
b_{11}	0.3573578	0.2524282	1.415681	0.158170749
b_{22}	0.6239873	0.1458927	4.277029	2.74013E-05
a_{11}	0.1240792	0.0914157	1.357307	0.175963997
a_{22}	0.0878121	0.1019191	0.861586	0.389778789
ρ_{12}	0.5811901	0.0338466	17.17132	0

17 (255)
MLE 1337.09

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012005	0.0006441	1.86368	0.06236697
c_{22}	0.0007278	0.0004942	1.47273	0.14082421
b_{11}	0.3565037	0.2522705	1.41318	0.158903741
b_{22}	0.6230922	0.1434213	4.344487	2.06477E-05
a_{11}	0.1242836	0.0908458	1.368073	0.172574058
a_{22}	0.0910359	0.1010002	0.901344	0.368312626
ρ_{12}	0.5842079	0.0335873	17.39371	0

18 (256)
MLE 1342.57

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011974	0.0006365	1.88108	0.05996072
c_{22}	0.0007328	0.0005016	1.46094	0.14403243
b_{11}	0.3563757	0.2491772	1.430209	0.153962918
b_{22}	0.6231697	0.1450884	4.295102	2.54091E-05
a_{11}	0.1262258	0.0906882	1.391866	0.165256991
a_{22}	0.0868466	0.1005151	0.864015	0.388445859
ρ_{12}	0.5837529	0.0335565	17.39612	0

Appendix 5.8A (Con't)

19 (257)
MLE 1348.39

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011953	0.00063	1.89724	0.057797
c_{22}	0.000744	0.0005139	1.44775	0.147686
b_{11}	0.3561588	0.2470432	1.4416863	0.1507
b_{22}	0.6184726	0.1490792	4.1486172	4.65E-05
a_{11}	0.1267072	0.0905099	1.3999265	0.162832
a_{22}	0.085366	0.1006178	0.8484187	0.397054
ρ_{12}	0.5838071	0.0334771	17.43901	0

20 (258)
MLE 1354.34

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011953	0.0006253	1.91162	0.055925
c_{22}	0.0007527	0.0005233	1.43848	0.150299
b_{11}	0.3550383	0.2459243	1.4436896	0.150136
b_{22}	0.6137294	0.1525735	4.0225159	7.73E-05
a_{11}	0.1269017	0.0903279	1.4048995	0.16135
a_{22}	0.0854088	0.1008487	0.8469004	0.397898
ρ_{12}	0.5843625	0.0333609	17.51641	0

21 (259)
MLE 1358.85

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0011926	0.0006244	1.9101	0.05612
c_{22}	0.0007335	0.0005088	1.44161	0.149412
b_{11}	0.3562989	0.2452623	1.4527259	0.147611
b_{22}	0.6282549	0.1450675	4.3307759	2.19E-05
a_{11}	0.1271232	0.09012	1.4105992	0.159663
a_{22}	0.0822727	0.1011975	0.8129911	0.417032
ρ_{12}	0.5868862	0.0332347	17.65885	0

22 (260)
MLE 1361.93

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012058	0.0006521	1.84897	0.0644618
c_{22}	0.0007319	0.0005105	1.43384	0.15161834
b_{11}	0.3612037	0.2499429	1.44514	0.149727113
b_{22}	0.6309234	0.1447402	4.35901	1.9419E-05
a_{11}	0.1285189	0.0924757	1.38976	0.16589525
a_{22}	0.083175	0.1021873	0.81395	0.416485466
ρ_{12}	0.5928689	0.0329657	17.9844	0

23 (261)
MLE 1367.59

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012043	0.0006605	1.82336	0.06824936
c_{22}	0.0007348	0.0005136	1.43074	0.15250522
b_{11}	0.3631872	0.2525864	1.43787	0.151778051
b_{22}	0.6312909	0.1450663	4.35174	2.00249E-05
a_{11}	0.1251962	0.0916635	1.36582	0.17327821
a_{22}	0.0801902	0.1010133	0.79386	0.428065942
ρ_{12}	0.5932241	0.0328252	18.0722	0

24 (262)
MLE 1372.76

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0012189	0.0006738	1.80905	0.07044331
c_{22}	0.0007299	0.0005033	1.4503	0.14697373
b_{11}	0.357344	0.2597994	1.37546	0.170276395
b_{22}	0.6334097	0.141901	4.46374	1.24164E-05
a_{11}	0.1234841	0.0915721	1.34849	0.178776943
a_{22}	0.0815095	0.1009422	0.80749	0.420189272
ρ_{12}	0.5947148	0.0326494	18.2152	0

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.8B: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(2)) for the 24 sample periods: The case of US/EAFE portfolio

*1 (238)***

MLE 1249.86

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009141	0.0005744	1.59137	0.111526
c_{22}	0.0004453	0.0003017	1.47587	0.139978
b_{11}	0.487236	0.251968	1.93372	0.054328
b_{22}	0.7384903	0.1476623	5.00121	1.1E-06
a_{11}	0.1064504	0.0939915	1.13255	0.258536
a_{22}	0.0810426	0.1017226	0.7967	0.426415
ρ_{12}	0.5569067	0.0365085	15.2542	0

2 (239)

MLE 1253.73

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009297	0.0005739	1.61999	0.105234
c_{22}	0.0004496	0.0003011	1.49342	0.135327
b_{11}	0.4825483	0.2508874	1.92337	0.055622
b_{22}	0.739282	0.1470227	5.02835	9.71E-07
a_{11}	0.1108309	0.0937973	1.1816	0.238539
a_{22}	0.0814789	0.1012718	0.80456	0.421875
ρ_{12}	0.5639729	0.0360515	15.6435	0

3 (240)

MLE 1259.06 631586

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000931	0.0005653	1.64692	0.099575
c_{22}	0.0004431	0.0002947	1.50388	0.132613
b_{11}	0.4798445	0.2504634	1.91583	0.05658
b_{22}	0.7437958	0.1477909	5.03276	9.51E-07
a_{11}	0.1134793	0.0940774	1.20623	0.22892
a_{22}	0.0781758	0.1025938	0.76199	0.446815
ρ_{12}	0.5628181	0.0361678	15.5613	0

4 (241)

MLE 1263.06

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009307	0.0005762	1.61512	0.1062842
c_{22}	0.0004273	0.0002813	1.51922	0.1287073
b_{11}	0.4813253	0.2507008	1.919919	0.0560585
b_{22}	0.7533768	0.1460559	5.1581393	5.237E-07
a_{11}	0.1092119	0.0944275	1.1565688	0.2486033
a_{22}	0.0778108	0.1016308	0.7656221	0.4446566
ρ_{12}	0.5608229	0.0365909	15.32684	0

5 (242)

MLE 1268.32

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009291	0.0005572	1.66755	0.095405
c_{22}	0.0004211	0.0002717	1.54981	0.1211877
b_{11}	0.4808858	0.2500913	1.922841	0.0556884
b_{22}	0.7590855	0.1391061	5.4568809	1.21E-07
a_{11}	0.1121915	0.0935211	1.1996378	0.2314679
a_{22}	0.0744846	0.1016297	0.732902	0.4643364
ρ_{12}	0.5632581	0.0364339	15.45973	0

6 (243)

MLE 1274.37 521427

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000932	0.0005612	1.66071	0.0967714
c_{22}	0.0004194	0.0002694	1.55666	0.1195521
b_{11}	0.4789325	0.2522052	1.8989794	0.0587715
b_{22}	0.7609424	0.1417006	5.3700715	1.863E-07
a_{11}	0.1107113	0.0929885	1.1905906	0.2349955
a_{22}	0.0721386	0.1013042	0.7120985	0.4770983
ρ_{12}	0.5632598	0.0363053	15.51454	0

7 (244)

MLE 1280.57

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009397	0.0005622	1.67144	0.094635
c_{22}	0.0004273	0.0002781	1.53668	0.124371
b_{11}	0.4728869	0.253339	1.866617	0.06318
b_{22}	0.7571777	0.1465329	5.167289	5.01E-07
a_{11}	0.111378	0.0927395	1.200976	0.230949
a_{22}	0.0714757	0.101573	0.703688	0.482312
ρ_{12}	0.5632821	0.0361171	15.596	0

8 (245)

MLE 1286.34

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009391	0.0005599	1.67746	0.093453
c_{22}	0.0004411	0.0002929	1.50619	0.132018
b_{11}	0.4728296	0.2519532	1.876657	0.061784
b_{22}	0.7500675	0.150476	4.984632	1.19E-06
a_{11}	0.1118897	0.0926836	1.207222	0.22854
a_{22}	0.072264	0.1018519	0.7095	0.478706
ρ_{12}	0.5643679	0.0359176	15.71287	0

9 (246)

MLE 1291.99 349998

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009346	0.0005538	1.68751	0.091506
c_{22}	0.0004301	0.0002797	1.53784	0.124088
b_{11}	0.4739234	0.249365	1.900521	0.058568
b_{22}	0.7554333	0.1483125	5.093525	7.13E-07
a_{11}	0.1117219	0.0919934	1.214456	0.225772
a_{22}	0.0718728	0.1011721	0.710401	0.478148
ρ_{12}	0.5655447	0.0357589	15.81548	0

Appendix 5.8B (con't)

10 (247)

MLE 1296.58

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009417	0.0005593	1.68365	0.092249
c_{22}	0.0004392	0.0002888	1.521	0.128259
b_{11}	0.4748756	0.2521758	1.88311	0.0609
b_{22}	0.7514282	0.1491288	5.03879	9.24E-07
a_{11}	0.1126277	0.092923	1.21205	0.226689
a_{22}	0.0716589	0.100876	0.71037	0.47817
ρ_{12}	0.5669173	0.0357002	15.8799	0

11 (248)

MLE 1302.62

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009273	0.0005572	1.66412	0.096088
c_{22}	0.000443	0.0002931	1.51105	0.130775
b_{11}	0.4824013	0.2505317	1.92551	0.055352
b_{22}	0.7492911	0.1492807	5.01934	1.01E-06
a_{11}	0.1088878	0.0918261	1.1858	0.236877
a_{22}	0.0714242	0.1008226	0.70841	0.479378
ρ_{12}	0.5669167	0.035591	15.9287	0

12 (249)

MLE 1307.53

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009317	0.0005612	1.66005	0.096905
c_{22}	0.000437	0.0002859	1.52827	0.126444
b_{11}	0.4795186	0.255127	1.87953	0.061389
b_{22}	0.753805	0.1493714	5.04652	8.91E-07
a_{11}	0.1079835	0.091829	1.17592	0.240797
a_{22}	0.070798	0.1019001	0.69478	0.487869
ρ_{12}	0.5666006	0.0357123	15.8657	0

13 (250)

MLE 1313.53

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009356	0.0005605	1.66929	0.0950604
c_{22}	0.000445	0.0002945	1.51083	0.1308322
b_{11}	0.475557	0.2553931	1.8620587	0.0638221
b_{22}	0.7494308	0.1485044	5.0465221	8.913E-07
a_{11}	0.1086759	0.091599	1.1864308	0.2366303
a_{22}	0.0713475	0.1016694	0.7017601	0.4835116
ρ_{12}	0.5671095	0.0355688	15.94404	0

14 (251)

MLE 1319.8

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009354	0.0005525	1.69286	0.0904815
c_{22}	0.0004468	0.0002965	1.50702	0.1318054
b_{11}	0.4727236	0.2525515	1.8717912	0.0624569
b_{22}	0.7478254	0.1480727	5.0503922	8.752E-07
a_{11}	0.1100463	0.0910625	1.2084694	0.2280611
a_{22}	0.0712212	0.101006	0.7051179	0.4814235
ρ_{12}	0.567357	0.0353765	16.03767	0

15 (252)

MLE 1323.93

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009404	0.000559	1.68218	0.0925339
c_{22}	0.0004468	0.0002927	1.52677	0.1268193
b_{11}	0.4752696	0.2539168	1.871753	0.0624622
b_{22}	0.750747	0.1462642	5.1328153	5.913E-07
a_{11}	0.109849	0.0914581	1.2010857	0.2309069
a_{22}	0.070931	0.1013888	0.6995933	0.4848617
ρ_{12}	0.5730356	0.0350451	16.35139	0

16 (253)

MLE 1329.17

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009381	0.0005619	1.66941	0.095037
c_{22}	0.0004547	0.000301	1.51074	0.130855
b_{11}	0.4777032	0.2524282	1.892432	0.059642
b_{22}	0.7475959	0.1458927	5.124286	6.16E-07
a_{11}	0.1088994	0.0914157	1.191255	0.234735
a_{22}	0.071093	0.1019191	0.697544	0.486141
ρ_{12}	0.5751487	0.0348888	16.48518	0

17 (254)

MLE 1334.27

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009379	0.0005584	1.67963	0.093029
c_{22}	0.000445	0.0002886	1.542	0.123072
b_{11}	0.4783754	0.2522705	1.89628	0.059129
b_{22}	0.7520403	0.1434213	5.243573	3.47E-07
a_{11}	0.1090134	0.0908458	1.199984	0.231334
a_{22}	0.0719511	0.1010002	0.712386	0.476921
ρ_{12}	0.578125	0.0346391	16.68997	0

18 (255)

MLE 1339.82

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009325	0.0005466	1.70597	0.088015
c_{22}	0.0004452	0.0002888	1.54135	0.123232
b_{11}	0.4795171	0.2491772	1.924402	0.055492
b_{22}	0.7536181	0.1450884	5.194198	4.4E-07
a_{11}	0.110606	0.0906882	1.21963	0.223807
a_{22}	0.0690174	0.1005151	0.686637	0.492977
ρ_{12}	0.5778529	0.0346471	16.67826	0

Appendix 5.8B (con't)

19 (256)

MLE 1345.61

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009328	0.000542	1.72087	0.085274
c_{22}	0.000452	0.0002966	1.52385	0.127546
b_{11}	0.4781422	0.2470432	1.93546	0.054113
b_{22}	0.7507591	0.1490792	5.03597	9.37E-07
a_{11}	0.1113478	0.0905099	1.23023	0.219821
a_{22}	0.0679974	0.1006178	0.6758	0.499822
ρ_{12}	0.5778269	0.0345254	16.7363	0

20 (257)

MLE 1351.54

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009339	0.0005398	1.73023	0.083589
c_{22}	0.0004638	0.0003096	1.49803	0.134124
b_{11}	0.4764651	0.2459243	1.93745	0.053869
b_{22}	0.7447309	0.1525735	4.88113	1.93E-06
a_{11}	0.1117493	0.0903279	1.23715	0.217245
a_{22}	0.0684283	0.1008487	0.67852	0.498096
ρ_{12}	0.5785001	0.0343223	16.8549	0

21 (258)

MLE 1356.01

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009369	0.0005389	1.73854	0.082116
c_{22}	0.0004478	0.000289	1.54915	0.121346
b_{11}	0.4751964	0.2452623	1.9375	0.053862
b_{22}	0.755361	0.1450675	5.20696	4.14E-07
a_{11}	0.1118991	0.09012	1.24167	0.215577
a_{22}	0.0668744	0.1011975	0.66083	0.509357
ρ_{12}	0.5807551	0.0343418	16.911	0

22 (259)

MLE 1358.93

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000946	0.0005617	1.68435	0.092114
c_{22}	0.0004676	0.0003091	1.51291	0.1303024
b_{11}	0.4804867	0.2499429	1.9223854	0.055746
b_{22}	0.7471491	0.1447402	5.1620001	5.14E-07
a_{11}	0.1127537	0.0924757	1.2192799	0.2239399
a_{22}	0.0693286	0.1021873	0.678446	0.4981453
ρ_{12}	0.5873089	0.0339473	17.30059	0

23 (260)

MLE 1364.67

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009329	0.0005597	1.66679	0.0955571
c_{22}	0.0004608	0.000301	1.53107	0.125753
b_{11}	0.4878152	0.2525864	1.9312807	0.0546309
b_{22}	0.7518117	0.1450663	5.1825372	4.657E-07
a_{11}	0.109556	0.0916635	1.1951974	0.2331945
a_{22}	0.0663261	0.1010133	0.6566072	0.5120652
ρ_{12}	0.5874454	0.0338481	17.35537	0

24 (261)

MLE 1369.98

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009446	0.0005712	1.6538	0.098168
c_{22}	0.0004573	0.0002977	1.53648	0.1244215
b_{11}	0.4831437	0.2597994	1.8596795	0.0641596
b_{22}	0.7541827	0.141901	5.3148502	2.446E-07
a_{11}	0.1081508	0.0915721	1.1810461	0.2387583
a_{22}	0.0658846	0.1009422	0.6526966	0.5145792
ρ_{12}	0.5889869	0.0337664	17.44299	0

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.8C: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(3)) for the 24 sample periods: The case of US/EAFE portfolio

*1 (237)***

MLE 1245.25

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009126	0.0005336	1.71044	0.08718521
c_{22}	0.00054	0.0003482	1.55064	0.12098715
b_{11}	0.4765451	0.251968	1.8912916	0.059794693
b_{22}	0.690373	0.1476623	4.6753491	4.90778E-06
a_{11}	0.1167546	0.0939915	1.242183	0.215386556
a_{22}	0.089492	0.1017226	0.879765	0.379870377
ρ_{12}	0.5528975	0.0365782	15.11548	0

2 (238)

MLE 1249.14

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009322	0.000534	1.7457	0.08086311
c_{22}	0.0005485	0.0003524	1.55628	0.11964036
b_{11}	0.4689741	0.2508874	1.869261	0.062809477
b_{22}	0.6899162	0.1470227	4.6925826	4.54393E-06
a_{11}	0.1225668	0.0937973	1.3067197	0.192563885
a_{22}	0.0899686	0.1012718	0.8883867	0.37522599
ρ_{12}	0.5601693	0.0361465	15.4972	0

3 (239)

MLE 1254.39

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009371	0.0005282	1.77416	0.07603688
c_{22}	0.0005385	0.000344	1.56522	0.11753079
b_{11}	0.4649918	0.2504634	1.8565264	0.064609125
b_{22}	0.6965392	0.1477909	4.7130056	4.14636E-06
a_{11}	0.1254935	0.0940774	1.3339385	0.183493752
a_{22}	0.0856836	0.1025938	0.8351737	0.404453986
ρ_{12}	0.5591477	0.0362369	15.43035	0

4 (240)

MLE 1258.27

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009359	0.0005378	1.74003	0.0818536
c_{22}	0.0005424	0.0003492	1.5535	0.1203044
b_{11}	0.467437	0.2507008	1.8645211	0.0634744
b_{22}	0.6965126	0.1460559	4.7688081	3.224E-06
a_{11}	0.1204586	0.0944275	1.2756733	0.2033095
a_{22}	0.0879577	0.1016308	0.8654635	0.3876524
ρ_{12}	0.5575775	0.0365546	15.25328	0

5 (241)

MLE 1263.4

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009334	0.0005224	1.787	0.0739381
c_{22}	0.0005324	0.0003355	1.58676	0.1125677
b_{11}	0.4680966	0.2500913	1.8717028	0.0624692
b_{22}	0.7046249	0.1391061	5.0653772	8.152E-07
a_{11}	0.1232429	0.0935211	1.3178079	0.1888297
a_{22}	0.0837647	0.1016297	0.8242143	0.4106396
ρ_{12}	0.56013	0.0363469	15.41067	0

6 (242)

MLE 1269.38

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009345	0.0005259	1.77702	0.0755644
c_{22}	0.0005316	0.0003359	1.58255	0.113523
b_{11}	0.4677132	0.2522052	1.8544944	0.0649002
b_{22}	0.7067967	0.1417006	4.9879584	1.174E-06
a_{11}	0.1208829	0.0929885	1.2999766	0.1948613
a_{22}	0.0804143	0.1013042	0.7937905	0.4281048
ρ_{12}	0.560202	0.0362219	15.46583	0

7 (243)

MLE 1275.59

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009437	0.000527	1.79073	0.07334
c_{22}	0.0005404	0.0003455	1.5644	0.11772
b_{11}	0.4605637	0.253339	1.817974	0.07032
b_{22}	0.7024741	0.1465329	4.793969	2.9E-06
a_{11}	0.1219445	0.0927395	1.314914	0.1898
a_{22}	0.0796709	0.101573	0.784371	0.4336
ρ_{12}	0.5602068	0.036023	15.55136	0

8 (244)

MLE 1281.31

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009414	0.0005252	1.79249	0.07305
c_{22}	0.0005517	0.0003554	1.55262	0.12051
b_{11}	0.4620083	0.2519532	1.833707	0.06794
b_{22}	0.6962998	0.150476	4.627314	6.1E-06
a_{11}	0.1218287	0.0926836	1.314457	0.18995
a_{22}	0.0804999	0.1018519	0.790362	0.4301
ρ_{12}	0.5613372	0.0358361	15.664	0

9 (245)

MLE 1286.93

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009374	0.0005206	1.80062	0.07176
c_{22}	0.0005486	0.0003512	1.56196	0.1183
b_{11}	0.4630296	0.249365	1.856834	0.06457
b_{22}	0.6978863	0.1483125	4.705513	4.3E-06
a_{11}	0.1214625	0.0919934	1.32034	0.18798
a_{22}	0.0808351	0.1011721	0.798986	0.42509
ρ_{12}	0.5625693	0.0356486	15.78098	0

Appendix 5.8C (con't)

10 (246)
MLE 1291.56

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009438	0.0005252	1.79717	0.07230836
c_{22}	0.0005526	0.0003547	1.55792	0.11925266
b_{11}	0.463782	0.2521758	1.8391216	0.067137799
b_{22}	0.6963529	0.1491288	4.6694738	5.03812E-06
a_{11}	0.122973	0.092923	1.3233864	0.186971474
a_{22}	0.0801271	0.100876	0.7943125	0.427801523
ρ_{12}	0.5639915	0.0356373	15.82589	0

11 (247)
MLE 1297.59

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009284	0.000523	1.77519	0.07586575
c_{22}	0.0005541	0.0003566	1.55373	0.12024833
b_{11}	0.4722741	0.2505317	1.885087	0.060631292
b_{22}	0.6953245	0.1492807	4.657832	5.30632E-06
a_{11}	0.1185247	0.0918261	1.2907516	0.198037017
a_{22}	0.0795565	0.1008226	0.7890742	0.430850685
ρ_{12}	0.5639707	0.0355313	15.87251	0

12 (248)
MLE 1302.53

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009347	0.0005273	1.77261	0.07629268
c_{22}	0.0005416	0.0003463	1.56373	0.11788055
b_{11}	0.4682516	0.255127	1.8353668	0.067693946
b_{22}	0.7042555	0.1493714	4.7147966	4.11314E-06
a_{11}	0.1178235	0.091829	1.2830742	0.200708895
a_{22}	0.0772433	0.1019001	0.7580301	0.449179771
ρ_{12}	0.5635835	0.0356475	15.8099	0

13 (249)
MLE 1308.48

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000938	0.0005275	1.77806	0.0753948
c_{22}	0.0005427	0.0003471	1.56345	0.1179472
b_{11}	0.4652243	0.2553931	1.8216008	0.0697656
b_{22}	0.7036087	0.1485044	4.7379645	3.706E-06
a_{11}	0.1179364	0.091599	1.2875294	0.1991552
a_{22}	0.0768237	0.1016694	0.7556225	0.4506196
ρ_{12}	0.5642084	0.0355228	15.88298	0

14 (250)
MLE 1314.74

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009382	0.000521	1.80071	0.0717483
c_{22}	0.0005447	0.0003492	1.56004	0.1187503
b_{11}	0.4622162	0.2525515	1.830186	0.0684675
b_{22}	0.7018713	0.1480727	4.7400443	3.671E-06
a_{11}	0.1193164	0.0910625	1.3102693	0.1913626
a_{22}	0.0765677	0.101006	0.7580505	0.4491675
ρ_{12}	0.564507	0.0353383	15.97438	0

15 (251)
MLE 1318.97

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009472	0.0005279	1.79436	0.072755
c_{22}	0.0005342	0.0003309	1.61446	0.1064287
b_{11}	0.4617661	0.2539168	1.8185721	0.0702283
b_{22}	0.7090162	0.1462642	4.8475042	2.252E-06
a_{11}	0.1203697	0.0914581	1.3161182	0.1893953
a_{22}	0.0769115	0.1013888	0.7585792	0.4488517
ρ_{12}	0.5700421	0.0349717	16.3001	0

16 (252)
MLE 1324.24

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009436	0.00053	1.78062	0.07497
c_{22}	0.000534	0.0003303	1.61691	0.1059
b_{11}	0.464918	0.2524282	1.841783	0.06675
b_{22}	0.7096387	0.1458927	4.864114	2.1E-06
a_{11}	0.119007	0.0914157	1.301822	0.19423
a_{22}	0.0765138	0.1019191	0.750731	0.45355
ρ_{12}	0.5719212	0.0348256	16.42243	0

17 (253)
MLE 1329.25

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009449	0.0005277	1.79057	0.07336
c_{22}	0.0005437	0.0003368	1.61425	0.10647
b_{11}	0.465072	0.2522705	1.843545	0.06649
b_{22}	0.7045375	0.1434213	4.912361	1.7E-06
a_{11}	0.1191664	0.0908458	1.311745	0.19086
a_{22}	0.0794502	0.1010002	0.786635	0.43228
ρ_{12}	0.575148	0.0344848	16.67831	0

18 (254)
MLE 1334.78

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009407	0.0005182	1.81529	0.06948
c_{22}	0.0005416	0.0003357	1.61326	0.10669
b_{11}	0.4657365	0.2491772	1.869097	0.06283
b_{22}	0.7074694	0.1450884	4.876125	2E-06
a_{11}	0.1207513	0.0906882	1.331501	0.18429
a_{22}	0.075788	0.1005151	0.753996	0.45159
ρ_{12}	0.5747476	0.0344576	16.67984	0

Appendix 5.8C (con't)

19 (255)
MLE 1340.53

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009365	0.000511	1.83271	0.06684506
c_{22}	0.0005475	0.0003436	1.59357	0.1110331
b_{11}	0.4666864	0.2470432	1.8890883	0.060090659
b_{22}	0.7054265	0.1490792	4.73189	3.80875E-06
a_{11}	0.1210821	0.0905099	1.3377776	0.182240505
a_{22}	0.0740982	0.1006178	0.7364326	0.462189712
ρ_{12}	0.5746882	0.0343402	16.73516	0

20 (256)
MLE 1346.36

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009368	0.0005115	1.83153	0.06702096
c_{22}	0.0005548	0.0003528	1.57271	0.11578651
b_{11}	0.4665488	0.2459243	1.8971238	0.059017117
b_{22}	0.7026141	0.1525735	4.6050856	6.70365E-06
a_{11}	0.1201929	0.0903279	1.3306284	0.184579456
a_{22}	0.0729855	0.1008487	0.7237134	0.469949481
ρ_{12}	0.5752825	0.0341945	16.82385	0

21 (257)
MLE 1350.56

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009321	0.0005226	1.78361	0.07448786
c_{22}	0.0005334	0.0003294	1.61944	0.10535254
b_{11}	0.4734722	0.2452623	1.930473	0.054731372
b_{22}	0.7166529	0.1450675	4.9401331	1.46794E-06
a_{11}	0.1154817	0.09012	1.2814207	0.201287785
a_{22}	0.0706075	0.1011975	0.69772	0.486030499
ρ_{12}	0.5774578	0.0343069	16.83213	0

22 (258)
MLE 1353.79

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009453	0.0005297	1.78469	0.0743111
c_{22}	0.000539	0.0003318	1.62429	0.1043142
b_{11}	0.4737188	0.2499429	1.8953078	0.0592583
b_{22}	0.7158185	0.1447402	4.9455392	1.431E-06
a_{11}	0.1196867	0.0924757	1.2942502	0.1968282
a_{22}	0.0715858	0.1021873	0.7005357	0.4842742
ρ_{12}	0.5840536	0.0338492	17.25458	0

23 (259)
MLE 1359.48

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009362	0.0005295	1.76812	0.0770415
c_{22}	0.0005379	0.0003313	1.62352	0.1044773
b_{11}	0.4790219	0.2525864	1.8964676	0.0591042
b_{22}	0.7179348	0.1450663	4.9490102	1.409E-06
a_{11}	0.1168259	0.0916635	1.2745087	0.203721
a_{22}	0.0687066	0.1010133	0.6801737	0.4970528
ρ_{12}	0.5843062	0.0337282	17.32397	0

24 (260)
MLE 1364.7

Var	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009472	0.0005399	1.75462	0.0793239
c_{22}	0.0005483	0.0003453	1.58798	0.1122914
b_{11}	0.4749586	0.2597994	1.828174	0.0687699
b_{22}	0.7150671	0.141901	5.0391959	9.227E-07
a_{11}	0.115201	0.0915721	1.2580367	0.2096062
a_{22}	0.0679707	0.1009422	0.6733625	0.5013673
ρ_{12}	0.5860662	0.0336233	17.43036	0

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.9A: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(1)) for the 24 sample periods: The case of Managed Futures/EAFE portfolio

1 (239) **

MLE 1186.28

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015136	0.000669879	2.25953	0.02385
c_{22}	0.0002668	0.000181533	1.46948	0.1417
b_{11}	0.2259043	0.338424754	0.6675171	0.50509
b_{22}	0.6304955	0.045407582	13.885247	1.5E-32
a_{11}	0.1080363	0.113949194	0.9481091	0.34403
a_{22}	0.3688009	0.054412173	6.7779124	9.4E-11
ρ_{12}	0.0266355	0.063401462	0.42011	0.67441

2 (240)

MLE 1190.67

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015312	0.000675757	2.2659	0.02346
c_{22}	0.0002542	0.000176208	1.44236	0.1492
b_{11}	0.2225715	0.340664526	0.653345	0.51416
b_{22}	0.6341525	0.043907354	14.442967	2.1E-34
a_{11}	0.1122124	0.115454968	0.9719146	0.33208
a_{22}	0.3693807	0.053613657	6.8896761	4.9E-11
ρ_{12}	0.0311725	0.06314629	0.49366	0.62155

3 (241)

MLE 1196.28

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001544	0.000679929	2.2708	0.02316
c_{22}	0.0002368	0.000168899	1.402	0.16092
b_{11}	0.2169075	0.346866575	0.625334	0.53235
b_{22}	0.6412233	0.041822323	15.332082	2.1E-37
a_{11}	0.1118057	0.115150261	0.9709546	0.33255
a_{22}	0.3667775	0.052785777	6.9484144	3.5E-11
ρ_{12}	0.0328003	0.062933015	0.52119	0.60223

4 (242)

MLE 1202.42

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001563154	0.000685688	2.27969	0.022626
c_{22}	0.000216098	0.000160129	1.34953	0.177168
b_{11}	0.207447892	0.357758088	0.5798552	0.562558
b_{22}	0.64951592	0.039298405	16.527794	1.95E-41
a_{11}	0.109098567	0.114562654	0.9523048	0.341905
a_{22}	0.365007885	0.051751202	7.0531287	1.87E-11
ρ_{12}	0.032054703	0.062608942	0.51198	0.608663

5 (243)

MLE 1207.96

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001563215	0.000685243	2.28126	0.022533
c_{22}	0.000210118	0.000157466	1.33437	0.182083
b_{11}	0.207683692	0.357031648	0.5816955	0.56132
b_{22}	0.650742624	0.038658543	16.833087	1.84E-42
a_{11}	0.109086497	0.114484666	0.9528481	0.34163
a_{22}	0.366509448	0.051410295	7.1291061	1.19E-11
ρ_{12}	0.0354765	0.062400884	0.56853	0.569678

6 (244)

MLE 1213.64

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001556987	0.000678241	2.29562	0.021697
c_{22}	0.000225892	0.000163875	1.37844	0.168067
b_{11}	0.207992657	0.354490903	0.5867362	0.557935
b_{22}	0.643206871	0.040702875	15.802492	5.4E-39
a_{11}	0.108552091	0.11369781	0.9547421	0.340673
a_{22}	0.368922118	0.052124565	7.0777016	1.62E-11
ρ_{12}	0.036922739	0.062388245	0.59182	0.55397

7 (245)

MLE 1219.78

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015481	0.00067	2.31793	0.02045
c_{22}	0.0001925	0.00015	1.28863	0.19753
b_{11}	0.2078494	0.35101	0.592151	0.55431
b_{22}	0.6612034	0.03639	18.16763	6.4E-47
a_{11}	0.1098449	0.11311	0.971167	0.33245
a_{22}	0.3594267	0.05064	7.097677	1.4E-11
ρ_{12}	0.0362093	0.06212	0.58292	0.55995

8 (246)

MLE 1225.51

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015474	0.00067	2.31601	0.02056
c_{22}	0.0001774	0.00014	1.24722	0.21232
b_{11}	0.2079393	0.35102	0.592384	0.55415
b_{22}	0.6680851	0.03464	19.28755	1.3E-50
a_{11}	0.1099809	0.11304	0.972978	0.33155
a_{22}	0.3569143	0.04989	7.154028	1E-11
ρ_{12}	0.0382968	0.06194	0.61829	0.53639

9 (247)

MLE 1231.59

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015433	0.00067	2.31884	0.0204
c_{22}	0.000159	0.00013	1.1925	0.23307
b_{11}	0.2081403	0.35046	0.593905	0.55314
b_{22}	0.6771174	0.03265	20.738	2.4E-55
a_{11}	0.1099435	0.11249	0.977387	0.32937
a_{22}	0.3525218	0.04908	7.181983	8.7E-12
ρ_{12}	0.0391591	0.06174	0.63427	0.52591

Appendix 5.9A (con't)

10 (248)
MLE 1236.54

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015696	0.000690823	2.27207	0.02308
c_{22}	0.0001412	0.000124496	1.13387	0.25685
b_{11}	0.2035757	0.363811051	0.5595643	0.5763
b_{22}	0.6843397	0.030954057	22.108239	1E-59
a_{11}	0.1088648	0.113987772	0.955057	0.34051
a_{22}	0.3508373	0.048232513	7.2738754	5E-12
ρ_{12}	0.0381938	0.061802077	0.618	0.53657

11 (249)
MLE 1242.83

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015635	0.000699407	2.23541	0.02539
c_{22}	0.0001234	0.000115979	1.06423	0.28723
b_{11}	0.2067405	0.366317221	0.5643756	0.57303
b_{22}	0.6917779	0.029419413	23.514335	4.1E-64
a_{11}	0.1045607	0.112699622	0.9277823	0.35446
a_{22}	0.3494162	0.047553999	7.3477772	3.2E-12
ρ_{12}	0.0388175	0.061544001	0.63073	0.52822

12 (250)
MLE 1247.8

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015663	0.000694175	2.25635	0.02405
c_{22}	0.0001779	0.000136435	1.3042	0.19216
b_{11}	0.2029344	0.367802792	0.5517478	0.58164
b_{22}	0.6696432	0.034481932	19.420119	4.7E-51
a_{11}	0.1047831	0.112681417	0.9299056	0.35336
a_{22}	0.3520934	0.049019772	7.1826822	8.6E-12
ρ_{12}	0.034802	0.061763114	0.56348	0.57311

13 (251)
MLE 1253.54

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001556606	0.000689783	2.25666	0.024029
c_{22}	0.000174213	0.000134349	1.29672	0.194726
b_{11}	0.205030043	0.364854393	0.5619503	0.574676
b_{22}	0.671906784	0.033992477	19.766338	3.44E-52
a_{11}	0.105392338	0.112615675	0.9358585	0.350291
a_{22}	0.350119466	0.048764875	7.1797471	8.78E-12
ρ_{12}	0.032654203	0.061627923	0.52986	0.596209

14 (252)
MLE 1259.76

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001544811	0.000682774	2.26255	0.023663
c_{22}	0.000152168	0.000123573	1.2314	0.218174
b_{11}	0.206771733	0.361328842	0.5722536	0.567688
b_{22}	0.685181228	0.031482474	21.763894	1.26E-58
a_{11}	0.106286223	0.112025909	0.9487646	0.343699
a_{22}	0.341800323	0.047710222	7.1640899	9.65E-12
ρ_{12}	0.031977427	0.061434748	0.52051	0.602708

15 (253)
MLE 1264.7

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001579025	0.000720133	2.19269	0.02833
c_{22}	0.000135242	0.000114908	1.17696	0.239213
b_{11}	0.200212934	0.382720685	0.5231307	0.601368
b_{22}	0.694289822	0.029788591	23.30724	1.8E-63
a_{11}	0.102795639	0.113402147	0.9064699	0.3656
a_{22}	0.336799734	0.0468525	7.1885114	8.33E-12
ρ_{12}	0.030488964	0.061622884	0.49477	0.620765

16 (254)
MLE 1269.8

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015685	0.00071	2.19432	0.02821
c_{22}	0.0001442	0.00012	1.21241	0.22535
b_{11}	0.205253	0.37529	0.546921	0.58494
b_{22}	0.6893053	0.03063	22.50093	5.9E-61
a_{11}	0.1041791	0.11423	0.912012	0.36268
a_{22}	0.3389054	0.04711	7.194209	8.1E-12
ρ_{12}	0.0251549	0.06154	0.40874	0.68273

17 (255)
MLE 1275.12

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015782	0.00072	2.18551	0.02885
c_{22}	0.0001347	0.00011	1.17718	0.23912
b_{11}	0.2009005	0.3828	0.524822	0.60019
b_{22}	0.6959233	0.02963	23.49073	4.9E-64
a_{11}	0.1047487	0.11432	0.916315	0.36043
a_{22}	0.3344632	0.0467	7.1627	9.7E-12
ρ_{12}	0.0211478	0.06147	0.34404	0.73082

18 (256)
MLE 1281.05

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015832	0.00073	2.17376	0.02972
c_{22}	0.0001217	0.00011	1.13262	0.25738
b_{11}	0.1981755	0.38871	0.509829	0.61064
b_{22}	0.7034054	0.02834	24.82209	4.2E-68
a_{11}	0.1044235	0.11422	0.914227	0.36152
a_{22}	0.3299252	0.04592	7.184399	8.5E-12
ρ_{12}	0.0215871	0.06138	0.3517	0.72506

Appendix 5.9A (Con't)

19 (257)

MLE 1287.17

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015785	0.000728675	2.16632	0.03029
c_{22}	0.0001085	0.000100434	1.08007	0.28011
b_{11}	0.1995595	0.388030066	0.5142887	0.60753
b_{22}	0.7099805	0.027217367	26.085571	7.1E-72
a_{11}	0.1040753	0.114193039	0.9113984	0.363
a_{22}	0.3269107	0.04518985	7.2341612	6.3E-12
ρ_{12}	0.0213867	0.061233885	0.34926	0.72689

20 (258)

MLE 1293.12

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015722	0.000723347	2.17349	0.02974
c_{22}	0.0001029	9.77424E-05	1.05252	0.29256
b_{11}	0.201255	0.384309153	0.5236798	0.60099
b_{22}	0.7122804	0.026793276	26.584296	2.5E-73
a_{11}	0.104084	0.113989107	0.9131045	0.36211
a_{22}	0.3267219	0.044890673	7.2781694	4.8E-12
ρ_{12}	0.0238643	0.061059933	0.39083	0.69592

21 (259)

MLE 1299.02

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0015681	0.000722628	2.17004	0.03
c_{22}	9.329E-05	9.28216E-05	1.00505	0.31487
b_{11}	0.2033174	0.381869636	0.5324263	0.59493
b_{22}	0.7163517	0.02608349	27.4638	6.9E-76
a_{11}	0.1041123	0.114098695	0.9124761	0.36244
a_{22}	0.3259957	0.044368362	7.3474817	3.2E-12
ρ_{12}	0.025867	0.060942106	0.42445	0.67124

22 (260)

MLE 1302.25

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.00160313	0.000741672	2.16151	0.030656
c_{22}	8.24356E-05	8.70161E-05	0.94736	0.343455
b_{11}	0.201714714	0.385423158	0.5233591	0.601209
b_{22}	0.721066756	0.025207697	28.605023	3.95E-79
a_{11}	0.107845991	0.117479635	0.9179973	0.359546
a_{22}	0.325136121	0.043570501	7.4622993	1.57E-12
ρ_{12}	0.030622326	0.06112107	0.50101	0.616363

23 (261)

MLE 1307.29

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001619824	0.00075594	2.14279	0.03213
c_{22}	0.00011053	9.73639E-05	1.13523	0.25628
b_{11}	0.196551482	0.397126866	0.4949337	0.621102
b_{22}	0.706794877	0.027214337	25.971417	1.55E-71
a_{11}	0.103040909	0.116066356	0.8877759	0.375554
a_{22}	0.330059311	0.0448362	7.3614471	2.92E-12
ρ_{12}	0.034003334	0.061110103	0.55643	0.577919

24 (262)

MLE 1312.35

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001630821	0.000753033	2.16567	0.030336
c_{22}	0.000124184	0.000103726	1.19723	0.231216
b_{11}	0.191465322	0.40071172	0.4778131	0.63322
b_{22}	0.696799759	0.028472131	24.473045	4.78E-67
a_{11}	0.102228994	0.115928455	0.8818283	0.378756
a_{22}	0.338003553	0.045462241	7.4348194	1.86E-12
ρ_{12}	0.029330228	0.060904468	0.48158	0.630106

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.9B: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(2)) for the 24 sample periods: The case of Managed Futures/EAFE portfolio

*1 (238)***

MLI 1194.383

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000960957	0.000606909	1.58336	0.113339
c_{22}	1.09432E-05	2.13524E-05	0.5125	0.608299
b_{11}	0.479240458	0.225036526	2.1296119	0.034226
b_{22}	0.914297091	0.011347443	80.572964	3E-175
a_{11}	0.090305677	0.103017022	0.8766093	0.381579
a_{22}	0.090294876	0.042152253	2.1421127	0.033195
ρ_{12}	0.06528858	0.070774544	0.92249	0.356275

2 (239)

MLI 1198.87

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.00098714	0.000609564	1.61942	0.105357
c_{22}	0.000009946	2.05503E-05	0.48398	0.628397
b_{11}	0.46907491	0.22627213	2.0730565	0.039239
b_{22}	0.91509635	0.011056787	82.763315	6.2E-178
a_{11}	0.09494367	0.104359051	0.909779	0.363856
a_{22}	0.089745266	0.04132769	2.1715529	0.030874
ρ_{12}	0.07071314	0.070302865	1.00584	0.314495

3 (240)

MLI 1204.652

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000978819	0.000610021	1.60457	0.108589
c_{22}	8.3994E-06	1.95554E-05	0.42952	0.667547
b_{11}	0.473392907	0.225472893	2.0995557	0.036817
b_{22}	0.916179562	0.010686903	85.729192	1.8E-181
a_{11}	0.094081475	0.104077514	0.9039558	0.366929
a_{22}	0.089008141	0.040237547	2.2120668	0.027908
ρ_{12}	0.073124398	0.070171211	1.04209	0.297372

4 (241)

MLE 1210.796

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009827	0.000620428	1.58393	0.113209
c_{22}	7.506E-06	1.89832E-05	0.39538	0.69256
b_{11}	0.4715451	0.229931338	2.0508081	0.041376
b_{22}	0.9167329	0.010482993	87.449541	1.8E-183
a_{11}	0.0917044	0.103473261	0.8862616	0.376367
a_{22}	0.0886888	0.039638782	2.2374245	0.026181
ρ_{12}	0.0720499	0.069937748	1.0302	0.302916

5 (242)

MLE 1216.393

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009834	0.000617534	1.59249	0.111275
c_{22}	7.714E-06	1.90013E-05	0.40595	0.684781
b_{11}	0.4710848	0.228892194	2.0581079	0.040664
b_{22}	0.9165744	0.010515564	87.163598	3.9E-183
a_{11}	0.0919493	0.103221264	0.8907982	0.373933
a_{22}	0.0888522	0.039728937	2.2364617	0.026245
ρ_{12}	0.0759962	0.069698239	1.09036	0.275554

6 (243)

MLE 1221.992

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009867	0.000616139	1.60144	0.10928
c_{22}	9.498E-06	1.98916E-05	0.4775	0.633005
b_{11}	0.4676346	0.229962182	2.0335282	0.043104
b_{22}	0.9155163	0.010882923	84.124125	1.4E-179
a_{11}	0.0919476	0.102751287	0.8948556	0.371765
a_{22}	0.0894505	0.040787553	2.1930831	0.029266
ρ_{12}	0.0772786	0.069832571	1.10663	0.268455

7 (244)

MLE 1228.243

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000994232	0.000609998	1.62989	0.10312
c_{22}	8.4689E-06	1.92521E-05	0.43989	0.66001
b_{11}	0.46089273	0.230342026	2.00091	0.04653
b_{22}	0.916301383	0.010602227	86.4254	3E-182
a_{11}	0.093342912	0.102427377	0.91131	0.36305
a_{22}	0.088887564	0.039967941	2.22397	0.02709
ρ_{12}	0.076511903	0.069558618	1.09996	0.27135

8 (245)

MLE 1234.191

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000992264	0.000606252	1.63672	0.10169
c_{22}	7.3041E-06	1.84848E-05	0.39514	0.69274
b_{11}	0.461641214	0.228768057	2.01794	0.04471
b_{22}	0.917207543	0.010309189	88.9699	3E-185
a_{11}	0.093580234	0.102254469	0.91517	0.36102
a_{22}	0.088234398	0.039128727	2.25498	0.02504
ρ_{12}	0.078888645	0.069360285	1.13737	0.25538

9 (246)

MLE 1240.499

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000985988	0.000600619	1.64162	0.10067
c_{22}	0.000005554	1.74386E-05	0.31849	0.75011
b_{11}	0.463440311	0.226879616	2.04267	0.04218
b_{22}	0.918431778	0.009925133	92.536	4E-189
a_{11}	0.09356848	0.101770907	0.9194	0.35881
a_{22}	0.087382994	0.037987511	2.30031	0.02229
ρ_{12}	0.07989514	0.069073797	1.15666	0.24741

Appendix 5.9B (con't)

10 (247)
MLI 1245.559

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000994091	0.00062331	1.59486	0.110744
c_{22}	3.7268E-06	1.63994E-05	0.22725	0.820227
b_{11}	0.465460786	0.232168662	2.004839	0.046108
b_{22}	0.919556627	0.009574442	96.042847	6.3E-193
a_{11}	0.092191804	0.103326343	0.8922391	0.373162
a_{22}	0.086685102	0.036958415	2.3454767	0.019821
ρ_{12}	0.078703509	0.069225767	1.13691	0.255576

11 (248)
MLI 1251.988

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000973076	0.000623415	1.56088	0.118552
c_{22}	2.3412E-06	0.000015679	0.14932	0.881299
b_{11}	0.476230048	0.230058441	2.0700394	0.039523
b_{22}	0.92031343	0.009347914	98.451204	2E-195
a_{11}	0.088468771	0.102047977	0.8669331	0.386848
a_{22}	0.086309531	0.036298275	2.377786	0.018204
ρ_{12}	0.079273751	0.068901669	1.15053	0.249924

12 (249)
MLI 1256.562

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000972784	0.000622879	1.56176	0.118346
c_{22}	7.8996E-06	0.000017941	0.44031	0.659713
b_{11}	0.474985571	0.230735168	2.0585747	0.040619
b_{22}	0.917943958	0.010067189	91.181758	1.1E-187
a_{11}	0.08826554	0.101961337	0.8656766	0.387536
a_{22}	0.086944127	0.038344353	2.2674558	0.024256
ρ_{12}	0.074181036	0.069326116	1.07003	0.284606

13 (250)
MLE 1262.408

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009741	0.000617895	1.57642	0.11493
c_{22}	7.962E-06	1.80017E-05	0.44227	0.658297
b_{11}	0.4724657	0.230223015	2.052209	0.041239
b_{22}	0.9178704	0.010106537	90.819478	2.8E-187
a_{11}	0.0890649	0.101971519	0.873429	0.383306
a_{22}	0.0869657	0.03846853	2.2606978	0.024678
ρ_{12}	0.0714789	0.069113445	1.03423	0.301031

14 (251)
MLE 1268.937

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009737	0.000609752	1.59685	0.110299
c_{22}	6.386E-06	1.70676E-05	0.37413	0.708304
b_{11}	0.4700027	0.228822414	2.0540064	0.041063
b_{22}	0.919103	0.009721096	94.547259	2.4E-191
a_{11}	0.0898388	0.101462746	0.8854363	0.376811
a_{22}	0.0860375	0.037332053	2.3046546	0.022044
ρ_{12}	0.0713623	0.0687471	1.03804	0.299251

15 (252)
MLE 1273.978

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009725	0.000637161	1.52625	0.126947
c_{22}	4.834E-06	1.62313E-05	0.29785	0.765821
b_{11}	0.4779421	0.234067556	2.0418982	0.04226
b_{22}	0.9200976	0.009411547	97.762638	1E-194
a_{11}	0.0862787	0.1025161	0.841611	0.400847
a_{22}	0.0853875	0.036416989	2.3447163	0.019861
ρ_{12}	0.0687432	0.069005851	0.99619	0.319156

16 (253)
MLE 1278.928

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000992069	0.000640929	1.54786	0.12166
c_{22}	5.8407E-06	1.66849E-05	0.35006	0.7263
b_{11}	0.468236676	0.237373234	1.97258	0.0497
b_{22}	0.919621673	0.009558683	96.208	4E-193
a_{11}	0.088575864	0.103715251	0.85403	0.39394
a_{22}	0.08551458	0.03686351	2.31976	0.0212
ρ_{12}	0.06213948	0.068804725	0.90313	0.36646

17 (254)
MLE 1284.355

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.001000078	0.000647305	1.54499	0.12235
c_{22}	5.9269E-06	1.67283E-05	0.3543	0.72311
b_{11}	0.464789016	0.240150032	1.93541	0.05412
b_{22}	0.919773051	0.009528621	96.5274	2E-193
a_{11}	0.088629301	0.103566283	0.85577	0.39298
a_{22}	0.085293071	0.036796536	2.31796	0.0213
ρ_{12}	0.057910408	0.068560112	0.84467	0.3983

18 (255)
MLE 1290.508

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000992481	0.000644916	1.53893	0.12382
c_{22}	4.4178E-06	1.58708E-05	0.27836	0.78073
b_{11}	0.468388107	0.238440452	1.96438	0.05064
b_{22}	0.920730263	0.00923403	99.7106	1E-196
a_{11}	0.087955488	0.103301713	0.85144	0.39538
a_{22}	0.084700278	0.035915202	2.35834	0.01916
ρ_{12}	0.058289522	0.068520797	0.85068	0.39495

Appendix 5.9B (con't)

19 (256)
MLI 1296.79

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000997259	0.000646443	1.54269	0.122907
c_{22}	2.8173E-06	1.50339E-05	0.18739	0.851352
b_{11}	0.46559471	0.239823833	1.941403	0.053385
b_{22}	0.921575643	0.00898067	102.61769	1.2E-199
a_{11}	0.087858507	0.103259634	0.8508505	0.395704
a_{22}	0.084294009	0.035160862	2.3973818	0.017281
ρ_{12}	0.058573139	0.068167954	0.85925	0.390204

20 (257)
MLI 1302.83

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000997439	0.000642869	1.55154	0.120772
c_{22}	2.3359E-06	1.47983E-05	0.15785	0.874578
b_{11}	0.46453203	0.23917712	1.9422093	0.053287
b_{22}	0.92179553	0.00892004	103.33984	2.4E-200
a_{11}	0.088121436	0.103209706	0.8538096	0.394065
a_{22}	0.084241322	0.034993383	2.40735	0.016828
ρ_{12}	0.06102848	0.068061825	0.89666	0.369899

21 (258)
MLI 1308.872

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000995241	0.000640398	1.5541	0.120161
c_{22}	1.1816E-06	1.42384E-05	0.08299	0.93386
b_{11}	0.465720793	0.237914563	1.9575128	0.051451
b_{22}	0.922290455	0.008778133	105.06681	4.9E-202
a_{11}	0.088144475	0.103326656	0.8530662	0.394477
a_{22}	0.08412024	0.034581863	2.4324959	0.01573
ρ_{12}	0.063068747	0.067989052	0.92763	0.353599

22 (259)
MLE 1312.15

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0010178	0.000667901	1.52394	0.127523
c_{22}	1.142E-07	1.37182E-05	0.00832	0.993359
b_{11}	0.4657846	0.242450448	1.921154	0.055902
b_{22}	0.9226151	0.008667484	106.44555	2.3E-203
a_{11}	0.0899939	0.106998952	0.8410728	0.401148
a_{22}	0.0840474	0.034208934	2.4568835	0.014727
ρ_{12}	0.0678706	0.068152346	0.99587	0.319316

23 (260)
MLE 1316.949

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009948	0.000674944	1.47394	0.140498
c_{22}	3.745E-06	1.48332E-05	0.25245	0.800695
b_{11}	0.4789533	0.241342047	1.9845415	0.048339
b_{22}	0.9212889	0.009026663	102.06306	4.4E-199
a_{11}	0.0854289	0.105414634	0.8104079	0.418512
a_{22}	0.0841658	0.035092635	2.3983894	0.017235
ρ_{12}	0.0717458	0.068056366	1.05421	0.291786

24 (261)
MLE 1321.475

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0010111	0.000689377	1.46671	0.142456
c_{22}	7.138E-06	1.61223E-05	0.44276	0.657939
b_{11}	0.4715891	0.248078595	1.9009666	0.058509
b_{22}	0.9194131	0.009557367	96.199415	4.3E-193
a_{11}	0.0847353	0.105432047	0.8036962	0.422371
a_{22}	0.0851024	0.036700281	2.31885	0.021247
ρ_{12}	0.0651707	0.068201027	0.95557	0.339291

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.9C: GARCH(1,1) coefficient estimates and maximum likelihood estimates values (using residual series from VAR(3)) for the 24 sample periods: The case of Managed Futures/EAFE portfolio

*1 (237)***
MLE 1185.35

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000966	0.0005893	1.63921	0.10117
c_{22}	0.0003851	0.0001322	2.91269	0.003583
b_{11}	0.4692864	0.2236643	2.0981733	0.03694
b_{22}	0.6683468	0.0463651	14.414852	2.56E-34
a_{11}	0.0973432	0.103128	0.9439067	0.346171
a_{22}	0.2388377	0.0699972	3.4121053	0.000757
ρ_{12}	0.0600603	0.0689614	0.87093	0.383794

2 (238)
MLE 1189.61

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009882	0.00059	1.67473	0.093987
c_{22}	0.000382	0.0001308	2.9212	0.003487
b_{11}	0.4606444	0.2241663	2.0549222	0.040974
b_{22}	0.665049	0.0460682	14.436184	2.17E-34
a_{11}	0.1026587	0.1046169	0.9812823	0.327446
a_{22}	0.244333	0.069159	3.5329173	0.000493
ρ_{12}	0.0642924	0.0686043	0.93715	0.348682

3 (239)
MLE 1195.11

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009789	0.0005884	1.6637	0.096173
c_{22}	0.000378	0.000129	2.93038	0.003386
b_{11}	0.4657053	0.2222629	2.09529	0.037198
b_{22}	0.6624796	0.0457057	14.494468	1.38E-34
a_{11}	0.1018839	0.1044603	0.9753361	0.33038
a_{22}	0.2487032	0.068108	3.6516007	0.00032
ρ_{12}	0.0664255	0.0685824	0.96855	0.33277

4 (240)
MLE 1201.07

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009806	0.0005972	1.64199	0.1005921
c_{22}	0.0003764	0.0001273	2.95546	0.003122
b_{11}	0.4654516	0.2256735	2.0624997	0.040241
b_{22}	0.6590927	0.0455536	14.468514	1.688E-34
a_{11}	0.0988587	0.1036964	0.9533472	0.3413774
a_{22}	0.2533176	0.0675544	3.7498308	0.000222
ρ_{12}	0.0653044	0.0682428	0.95694	0.3385965

5 (241)
MLE 1206.49

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009682	0.0005915	1.63673	0.1016869
c_{22}	0.0003722	0.0001259	2.95718	0.0031047
b_{11}	0.4732669	0.2210835	2.1406702	0.033313
b_{22}	0.6566727	0.0451045	14.558922	8.376E-35
a_{11}	0.0972321	0.1030774	0.9432922	0.346484
a_{22}	0.25864	0.0663198	3.8998892	0.0001251
ρ_{12}	0.0693747	0.0679517	1.02094	0.3072827

6 (242)
MLE 1212.24

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009694	0.000591	1.64035	0.1009334
c_{22}	0.0003724	0.0001262	2.95174	0.0031599
b_{11}	0.47135	0.2219105	2.1240542	0.0346929
b_{22}	0.6553785	0.0452236	14.49195	1.408E-34
a_{11}	0.0965879	0.1025178	0.9421574	0.3470634
a_{22}	0.2600378	0.0659848	3.9408758	0.0001066
ρ_{12}	0.0708533	0.0678879	1.04368	0.2966334

7 (243)
MLE 1218.25

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009818	0.0005871	1.67236	0.094454
c_{22}	0.0003687	0.0001236	2.98354	0.002849
b_{11}	0.46219	0.223513	2.06784	0.039731
b_{22}	0.6558063	0.0446632	14.6834	3.19E-35
a_{11}	0.0982501	0.1022931	0.96048	0.337786
a_{22}	0.2603261	0.0655621	3.97068	9.49E-05
ρ_{12}	0.0700532	0.0676147	1.03606	0.300172

8 (244)
MLE 1223.93

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009727	0.0005839	1.66598	0.095717
c_{22}	0.0003623	0.0001203	3.01268	0.00259
b_{11}	0.4677877	0.220631	2.12023	0.035018
b_{22}	0.6555249	0.0439351	14.9203	5.08E-36
a_{11}	0.0970644	0.1019588	0.952	0.34206
a_{22}	0.2630109	0.0646512	4.06815	6.44E-05
ρ_{12}	0.0720173	0.0674888	1.0671	0.285926

9 (245)
MLE 1229.94

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009644	0.0005789	1.66595	0.095724
c_{22}	0.000355	0.000117	3.03357	0.002417
b_{11}	0.4709323	0.21862	2.15411	0.032231
b_{22}	0.6554904	0.0432019	15.1727	7.16E-37
a_{11}	0.0966687	0.1014667	0.95271	0.341698
a_{22}	0.2655504	0.063893	4.15618	4.51E-05
ρ_{12}	0.072883	0.0673026	1.08292	0.278846

Appendix 5.9C (con't)

10 (246)
MLE 1234.77

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009629	0.0005952	1.61778	0.105711
c_{22}	0.0003468	0.0001137	3.05067	0.002283
b_{11}	0.4770726	0.221096	2.1577621	0.031943
b_{22}	0.6543235	0.0424388	15.418048	1.07E-37
a_{11}	0.0952419	0.1028939	0.9256324	0.355571
a_{22}	0.2702948	0.062976	4.2920285	2.57E-05
ρ_{12}	0.0720685	0.0674285	1.06881	0.285154

11 (247)
MLE 1240.95

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.000936	0.0005947	1.57381	0.115533
c_{22}	0.0003382	0.0001103	3.06634	0.002167
b_{11}	0.491491	0.2179632	2.2549266	0.025044
b_{22}	0.6533247	0.0416602	15.682229	1.37E-38
a_{11}	0.0905277	0.1014797	0.8920774	0.373249
a_{22}	0.2755953	0.0621455	4.4346769	1.41E-05
ρ_{12}	0.0727339	0.0671105	1.08379	0.278456

12 (248)
MLE 1246.04

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009374	0.0005947	1.57623	0.114973
c_{22}	0.0003488	0.0001165	2.99476	0.002747
b_{11}	0.4892176	0.2190914	2.232939	0.02648
b_{22}	0.6574104	0.0427072	15.393432	1.29E-37
a_{11}	0.0904692	0.1013801	0.892376	0.373089
a_{22}	0.2650922	0.0630504	4.2044516	3.7E-05
ρ_{12}	0.0695087	0.067274	1.03322	0.301502

13 (249)
MLE 1251.7

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009348	0.0005905	1.58299	0.1134231
c_{22}	0.0003417	0.0001134	3.01283	0.0025883
b_{11}	0.4895606	0.2178496	2.2472414	0.0255377
b_{22}	0.6616858	0.0419055	15.789958	5.951E-39
a_{11}	0.090428	0.101263	0.8930015	0.3727546
a_{22}	0.2618837	0.0629413	4.1607629	4.427E-05
ρ_{12}	0.0673103	0.067103	1.00309	0.3158175

14 (250)
MLE 1257.91

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009383	0.0005839	1.60705	0.1080445
c_{22}	0.0003335	0.0001091	3.05738	0.0022328
b_{11}	0.4849787	0.2174403	2.2303998	0.02665
b_{22}	0.6651368	0.0408589	16.278857	1.344E-40
a_{11}	0.0916081	0.1008833	0.9080603	0.3647611
a_{22}	0.260001	0.0623726	4.1685106	4.289E-05
ρ_{12}	0.067242	0.0668351	1.00609	0.3143727

15 (251)
MLE 1257.9

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009342	0.0005794	1.61229	0.1068978
c_{22}	0.000333	0.0001093	3.04628	0.0023169
b_{11}	0.4867935	0.2152972	2.2610308	0.0246572
b_{22}	0.66561	0.0408627	16.288926	1.243E-40
a_{11}	0.0915231	0.1006081	0.9096991	0.3638977
a_{22}	0.2596089	0.062478	4.1552036	4.529E-05
ρ_{12}	0.0666785	0.0670178	0.99494	0.3197671

16 (252)
MLE 1262.65

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009316	0.0006057	1.53794	0.124064
c_{22}	0.000326	0.0001069	3.0499	0.002289
b_{11}	0.4964302	0.2196811	2.25978	0.024736
b_{22}	0.6642407	0.0403601	16.4579	3.36E-41
a_{11}	0.086833	0.1015212	0.85532	0.393231
a_{22}	0.2639257	0.0616815	4.27885	2.72E-05
ρ_{12}	0.0641667	0.0671212	0.95598	0.339081

17 (253)
MLE 1267.54

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009657	0.0006134	1.57448	0.115377
c_{22}	0.000328	0.0001066	3.0763	0.002096
b_{11}	0.4792352	0.2256458	2.12384	0.034711
b_{22}	0.6643753	0.0405327	16.3911	5.63E-41
a_{11}	0.0901017	0.1022888	0.88086	0.379281
a_{22}	0.2626016	0.0620409	4.23272	3.29E-05
ρ_{12}	0.0590062	0.0668708	0.88239	0.377566

18 (254)
MLE 1272.99

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009598	0.0006094	1.57509	0.115237
c_{22}	0.000324	0.0001046	3.09902	0.001942
b_{11}	0.48249	0.2231566	2.16211	0.031602
b_{22}	0.664544	0.04009	16.5763	1.34E-41
a_{11}	0.0897678	0.1022563	0.87787	0.380896
a_{22}	0.2637355	0.0615099	4.2877	2.62E-05
ρ_{12}	0.0554017	0.0669561	0.82743	0.407991

Appendix 5.9C (con't)

19 (255)
MLE 1284.75

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009638	0.0006098	1.58051	0.113991
c_{22}	0.0003074	9.75E-05	3.15258	0.001618
b_{11}	0.4804507	0.2237442	2.1473214	0.032774
b_{22}	0.66609	0.0384018	17.345266	3.54E-44
a_{11}	0.089085	0.1019895	0.873472	0.383283
a_{22}	0.2683749	0.059999	4.4729917	1.19E-05
ρ_{12}	0.0565276	0.0664463	0.85073	0.394921

20 (256)
MLE 1290.63

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009619	0.0006083	1.58116	0.113842
c_{22}	0.0003028	9.547E-05	3.17186	0.001515
b_{11}	0.4804711	0.223681	2.1480195	0.032718
b_{22}	0.665131	0.0380253	17.491804	1.15E-44
a_{11}	0.0890961	0.1019871	0.873601	0.383212
a_{22}	0.2719441	0.0596835	4.5564348	8.3E-06
ρ_{12}	0.0582379	0.0662542	0.87901	0.379398

21 (257)
MLE 1296.42

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009555	0.0006051	1.5791	0.114314
c_{22}	0.000295	9.203E-05	3.20518	0.00135
b_{11}	0.484265	0.2214355	2.1869348	0.029717
b_{22}	0.665372	0.0372605	17.857297	6.9E-46
a_{11}	0.0884286	0.1019708	0.8671961	0.386704
a_{22}	0.2752369	0.0589355	4.6701406	5.02E-06
ρ_{12}	0.0598776	0.0661797	0.90477	0.365585

22 (258)
MLE 1299.41

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009612	0.0006213	1.54711	0.1218364
c_{22}	0.0002867	8.865E-05	3.23374	0.0012218
b_{11}	0.4925649	0.2203208	2.2356709	0.0262974
b_{22}	0.6657237	0.0364469	18.265578	3.025E-47
a_{11}	0.0889844	0.1050079	0.8474067	0.3976163
a_{22}	0.2788305	0.05816	4.794194	2.873E-06
ρ_{12}	0.0639987	0.0664107	0.96368	0.3352063

23 (259)
MLE 1304.77

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009366	0.0006255	1.49732	0.1343091
c_{22}	0.0002939	9.211E-05	3.19067	0.0014194
b_{11}	0.5064763	0.2185181	2.3177776	0.0213068
b_{22}	0.6618289	0.037218	17.782488	1.226E-45
a_{11}	0.0844481	0.1034338	0.8164458	0.4150582
a_{22}	0.2807153	0.0582786	4.8167829	2.592E-06
ρ_{12}	0.0668381	0.0662623	1.00869	0.3131235

24 (260)
MLE 1309.86

Vars	Coeff	Std Error	T-Stat	Signif
c_{11}	0.0009612	0.0006403	1.50107	0.133337
c_{22}	0.0003088	9.607E-05	3.21485	0.0013051
b_{11}	0.4946292	0.2261265	2.1874006	0.0296827
b_{22}	0.65129	0.0387435	16.810302	2.198E-42
a_{11}	0.0845693	0.1036568	0.8158583	0.4153935
a_{22}	0.2880838	0.0582376	4.9466969	1.424E-06
ρ_{12}	0.062392	0.0660128	0.94515	0.3445824

Note: (**) indicates the number of sample periods. The values in bracket is the number of data points used for the sample period.

Appendix 5.10A: Coefficient estimates of vector autoregression of lag 1 for the 24 sample periods: The case of the EAFE/US portfolio

Regression equations for the indexes underlying the EAFE/US portfolio as follows

$$R_{1,t} = \alpha_{1,0} + \sum_{i=1}^{2} \beta_{1,i} R_{i,t-1} + \varepsilon_{1,t}$$

$$R_{2,t} = \alpha_{2,0} + \sum_{i=1}^{2} \beta_{2,i} R_{i,t-1} + \varepsilon_{2,t}$$

where, i = 1 denotes the EAFE index returns, i = 2 denotes the US index returns. $R_{1,t}$ represents the regression equation where the EAFE index is is the dependent variable. $R_{2,t}$ represents the regression equation where the US index is the dependent variable. The following lists the coefficient estimates capturing the assets' returns for the one time lags.

Sample	EAFE			US		
Periods	$\alpha_{1,0}$	$\beta_{1,1}$	$\beta_{1,2}$	$\alpha_{2,0}$	$\beta_{2,1}$	$\beta_{2,2}$
1	0.008222[a]	0.02909	0.16929[b]	0.011212[a]	0.11308	0.07526
2	0.007985[a]	0.0217	0.16361[b]	0.010973[a]	0.10734	0.06779
3	0.008354[a]	0.01606	0.15849[b]	0.010982[a]	0.10721	0.06765
4	0.00842[a]	0.01822	0.15696[b]	0.011372[a]	0.09823	0.0803
5	0.008279[a]	0.02436	0.14337[c]	0.011239[a]	0.08546	0.08607
6	0.008371[a]	0.02341	0.14252[c]	0.011319[a]	0.08471	0.08524
7	0.008419[a]	0.02358	0.14256[c]	0.011351[a]	0.08474	0.08536
8	0.008246[a]	0.02258	0.14239[c]	0.011226[a]	0.08462	0.08463
9	0.008407[a]	0.02031	0.14196[c]	0.011513[a]	0.08385	0.08055
10	0.008161[a]	0.02046	0.13483[c]	0.011399[a]	0.08055	0.08063
11	0.008102[a]	0.02218	0.13451[c]	0.011273[a]	0.07987	0.0843
12	0.008001[a]	0.02216	0.13568[c]	0.010935[a]	0.08377	0.08422
13	0.007903[a]	0.0215	0.13821[c]	0.010756[a]	0.08842	0.08301
14	0.007995[a]	0.02119	0.13713[c]	0.010843[a]	0.08738	0.08271
15	0.007708[b]	0.01996	0.13629[c]	0.010516[a]	0.08644	0.08131
16	0.007389[b]	0.02401	0.14159[c]	0.010173[a]	0.09212	0.08566
17	0.007726[b]	0.01958	0.13709[c]	0.010637[a]	0.08594	0.07958
18	0.007598[b]	0.01821	0.13202[c]	0.010609[a]	0.08484	0.07928
19	0.007423[b]	0.02252	0.12976[c]	0.010541[a]	0.08397	0.08094
20	0.007257[b]	0.02553	0.12925[c]	0.010425[a]	0.08361	0.08305
21	0.007033[b]	0.02843	0.13003[c]	0.010012[a]	0.08504	0.08838
22	0.006393[b]	0.02884	0.1465[b]	0.009493[a]	0.09842	0.08871
23	0.006673[b]	0.02084	0.14356[b]	0.009695[a]	0.0963	0.08295
24	0.006831[b]	0.02317	0.14305[b]	0.009948[a]	0.09549	0.08668

Note: ([a]) indicates the parameters significant at 1%; ([b]) indicates parameters signifcant at 5% & ([c]) indicates parameters significant at 10%.

Appendix 5.10B: Coefficient estimates of vector autoregression of lag 3 for the 24 sample periods: The case of the EAFE/MAR portfolio

Regression equations for the indexes underlying the EAFE/MAR portfolio as follows

$$R_{1,t} = \alpha_{1,0} + \sum_{i=1}^{2} \beta_{1,i} R_{i,t-1} + \sum_{i=1}^{2} \lambda_{1,i} R_{i,t-2} + \sum_{i=1}^{2} \theta_{1,i} R_{i,t-3} + \varepsilon_{1,t} \text{ – Equation (1); } R_{2,t} = \alpha_{2,0} + \sum_{i=1}^{2} \beta_{2,i} R_{i,t-1} + \sum_{i=1}^{2} \lambda_{2,i} R_{i,t-2} + \sum_{i=1}^{2} \theta_{2,i} R_{i,t-3} + \varepsilon_{2,t} \text{ – Equation (2)}$$

where, i = 1 denotes the EAFE index returns, i = 2 denotes the MAR index returns. $R_{1,t}$ represents the regression equation where the EAFE index is the dependent variable. $R_{2,t}$ represents the regression equation where the MAR index is the dependent variable. The following lists the coefficient estimates capturing the assets' returns for the three time lags.

Sample	EAFE							MAR						
Periods	$\alpha_{1,0}$	$\beta_{1,1}$	$\beta_{1,2}$	$\lambda_{1,1}$	$\lambda_{1,2}$	$\theta_{1,1}$	$\theta_{1,2}$	$\alpha_{2,0}$	$\beta_{2,1}$	$\beta_{2,2}$	$\lambda_{2,1}$	$\lambda_{2,2}$	$\theta_{2,1}$	$\theta_{2,2}$
1	**0.00929**	***0.11786***	0.00484	-0.06841	0.0769	0.0375	-0.01361	**0.0164**	***-0.1207***	***-0.1215***	-0.06845	0.09981	0.02923	-0.0371
2	*0.00905*	***0.10874***	-0.0031	-0.07225	0.0768	0.03481	-0.00508	**0.01632**	***-0.1208***	***-0.1223***	-0.0657	0.09687	0.02667	-0.03833
3	*0.00924*	0.09945	0.00378	-0.06759	0.07488	0.0357	-0.00306	**0.0164**	***-0.1215***	***-0.122***	-0.06487	0.09302	0.02952	-0.03641
4	*0.0093*	0.10089	0.00115	-0.06558	0.07522	0.0351	-0.00282	**0.01633**	***-0.122***	***-0.1211***	-0.0652	0.09099	0.03323	-0.03924
5	*0.00901*	0.09992	-0.004	-0.05711	0.07702	0.03407	-0.00095	**0.01613**	***-0.1208***	***-0.1218***	-0.06389	0.09031	0.02963	-0.03332
6	*0.0091*	0.09834	-0.0034	-0.05567	0.07619	0.03345	-0.00079	**0.01633**	***-0.1226***	***-0.1232***	-0.06353	0.08677	0.03097	-0.0301
7	*0.00915*	0.09863	-0.00438	-0.05525	0.07679	0.03303	-0.00106	**0.01622**	***-0.1239***	***-0.1223***	-0.06294	0.08613	0.03312	-0.03103
8	*0.00892*	0.09777	-0.00567	-0.051	0.07833	0.03045	0.0007	**0.01611**	***-0.1232***	***-0.1236***	-0.06207	0.0857	0.03248	-0.02892
9	*0.00908*	0.09515	-0.00466	-0.05052	0.07736	0.02945	0.00228	**0.01616**	***-0.1235***	***-0.1239***	-0.06153	0.0848	0.03283	-0.02876
10	*0.0087*	0.09049	0.00205	-0.05338	0.07647	0.03221	0.0048	**0.01616**	***-0.1235***	***-0.1239***	-0.06155	0.08483	0.03279	-0.02874
11	*0.00862*	0.09246	0.00106	-0.05221	0.07638	0.03186	0.00519	**0.01607**	***-0.1236***	***-0.1244***	-0.06109	0.08717	0.03162	-0.02736
12	*0.00852*	0.09284	0.00413	-0.05355	0.07684	0.03173	0.00479	**0.01634**	***-0.1247***	***-0.1241***	-0.0601	0.08624	0.02408	-0.02405
13	*0.00835*	0.09435	0.00475	-0.04904	0.07434	0.0321	0.00438	**0.01649**	***-0.1226***	***-0.1244***	-0.05975	0.08493	0.02354	-0.02796
14	*0.00839*	0.09377	0.0043	-0.04937	0.07481	0.03295	0.0042	**0.01646**	***-0.1229***	***-0.1249***	-0.05964	0.08529	0.02382	-0.02776
15	*0.00812*	0.09183	0.00859	-0.04573	0.07581	0.02981	-0.00142	**0.0165**	***-0.123***	***-0.1245***	-0.05892	0.08553	0.02327	-0.02822
16	*0.00781*	0.10028	0.00622	-0.04245	0.07502	0.03039	-0.00328	**0.01667**	***-0.1225***	***-0.1248***	-0.05786	0.08074	0.02461	-0.03009
17	*0.00809*	0.0945	-0.0007	-0.04058	0.07773	0.03156	-0.00393	**0.01653**	*-0.1239*	*-0.1254*	-0.05754	0.08363	0.02808	-0.03102
18	*0.00785*	0.09001	0.00464	-0.03469	0.07972	0.02969	-0.00476	**0.01649**	*-0.1235*	*-0.1257*	-0.05769	0.08281	0.02906	-0.02995
19	*0.00764*	0.09306	0.00046	-0.0297	0.08008	0.03136	-0.00596	**0.01646**	*-0.1235*	*-0.1255*	-0.05784	0.08319	0.02854	-0.02933
20	*0.00746*	0.0954	0.00291	-0.03305	0.0802	0.03167	-0.00419	**0.01635**	*-0.1234*	*-0.1253*	-0.0567	0.0847	0.03012	-0.03149
21	*0.00716*	0.09846	0.00575	-0.02991	0.08171	0.03151	-0.00407	**0.01625**	*-0.1229*	*-0.1254*	-0.05666	0.08571	0.03106	-0.03045
22	***0.00639***	0.10835	0.01207	-0.02214	0.08405	0.03491	-0.00385	**0.01614**	*-0.1226*	*-0.1249*	-0.05663	0.0871	0.03194	-0.02937
23	*0.0067*	0.09981	0.00964	-0.02453	0.08338	0.03464	-0.00513	**0.01646**	*-0.1233*	*-0.1252*	-0.05795	0.0782	0.02942	-0.03185
24	*0.00691*	0.10267	0.00079	-0.02733	0.08586	0.03407	-0.00529	**0.0162**	*-0.1264*	*-0.1245*	-0.05775	0.07462	0.0405	-0.02834

Note: The values in bold are statistically significant at 1%; in italic are significant at 5%; in bold and italic are significant at 10%.

Chapter 6

Asset Allocation with Managed Futures for UK investors: An application using an Active Currency Management approach

6.0 Introduction to the Chapter

This chapter uses an Active Currency Management[1] approach to simulate the possible returns in US£'s achievable by UK investors that have allocated some proportion of their portfolio to Managed Futures. The main issue here concerns the assumptions by which US$ denominated asset returns are converted into US£'s. The main analysis is focused on evaluating whether an Active Currency Management strategy, i.e., allowing for a conditional choice of either spot rates or forward contracts in the conversion process, has a significant effect upon portfolio returns in UK pounds. This chapter, therefore, does not focus directly on assessing the incremental benefits of Managed Futures investments. It is about the incremental benefits of adopting Active Currency Management, relative to the "pure" use of forward contracts and spot rates, to a UK portfolio that uses Managed Futures. Assessing the effects of adopting an Active Currency Management approach is important given the increasing use of Managed Futures as an asset class and its off-shore foreign currency investment status to UK investors. This means that managing currency exposure will naturally become more of a concern as UK investors increase their exposure to international equity and Managed Futures funds. The development of the foreign

[1] "Active Currency Management", "dynamic hedging" and "currency overlay programs" are used interchangeably here as they refer to the same phenomenon, namely, the use of algorithm-based trading strategies (Dunis & Levy, 2002).

exchange market following the de-pegging of the US$ from Gold in 1971 has created the conditions for the development and use of Active Currency Management strategies in managing foreign currency exposure. The empirical analysis of this chapter first examines the development of the foreign currency markets and the Active Currency Management sector and then presents the various alternative opportunities available to UK investors to hedge and/or profit from this currency exposure.

The adoption in 1971 of the floating exchange rate regime that followed the US$'s de-pegging from the Gold Standard, introduced a significant new element of uncertainty to international transactions and the values of foreign assets. The possibility arose that large adverse movements in relative exchange rates could potentially completely wipe out the profit margins of exporters, importers and institutional investors exposed to the depreciating currency. This new source of risk naturally created an increased demand among corporations and portfolio managers for insurance and hedging instruments to eliminate unwanted exposure to exchange rate risks. Hence, today a high proportion of the trading volume on foreign exchanges is actually attributable to foreign exchange trading for the purpose of hedging currency exposures rather than being simply related to international transactions in goods and services.

The growth of the Eurocurrency market was also given a boost by the ending of the system of fixed exchange rates in 1971. In fact, a triennial survey of the Bank for International Settlement shows that in 1998, the volume of currency trading in London denominated in US$s was significantly greater than the volumes traded within the US itself. The survey also shows that in 1998, there were 213 foreign exchange dealer institutions in the United Kingdom reporting trading activities to the Bank of England, compared with only 93 in the United States that reported to the Federal Reserve Bank of New York. In terms of foreign exchange trading, London benefits not only from its proximity to the major Eurocurrency credit markets and other financial markets, but also from its geographical location and time zone. In addition to being open when the numerous other financial centers in Europe are open, London's morning hours overlap with the late hours in a number of Asian and Middle East markets; London's afternoon sessions correspond to the morning periods in the large North American market. Thus, surveys have indicated that there are more foreign exchange trading in dollars and in marks in London than in the USA and Germany. However, the bulk of trading in London, about 85 percent, is accounted for by foreign-owned (non-U.K. owned) institutions, with U.K.-based dealers of North American institutions reporting 49 percent, or three times the share of U.K.-owned institutions there. The comparative advantage of London as the leading financial centre for foreign exchange dealings ensures that, compared to the US, it has relatively deeper and more liquid currency trading markets.

Industry surveys have shown that Commodity Trading Advisors are typically primarily involved in over-the-counter (OTC) market transactions (the Eurocurrency market being one example). In comparison to exchange-based instruments, which provide alternative currency hedging tools (such as currency futures contracts), the OTC markets provide additional flexibility and convenience. For example[2], it was found that the OTC market is able to provide minimum trades that are only about 20% of the value of the typical futures contract. Moreover, OTC participants are free to decide between themselves whatever contractual terms they wish, e.g., contract size and expiration dates. They can also

[2] The example is from an article from Anonymous (1991), the author is not named, see reference for details.

trade round the clock in some cross rates not readily available in the futures exchange markets.

In the UK, the Managed Futures trading and investing industry largely escapes regulation by the UK financial regulator because most firms are located off-shore and are, therefore, not licensed to market their services to the general public (see, for example, Fox-Andrews and Meaden, 1995). Even so, provided that companies in off-shore locations involved in Managed Futures activities are also registered as Commodity Trading Advisors (CTA) and provided they also sell their services to the US markets at the same time, then they are subjected to regulation by the CFTC (See www.aima.org/aimasite/indexfrm.htm). Information regarding the regulatory regime that each Managed Futures companies operate under is normally listed in their 'Risk disclosure' documents[3].

The nature of regulation implies that for off shore based CTAs, apart from being able to access the US futures exchanges for conducting their investment activities, are also open to the wide and liquid foreign exchange markets. This offers CTAs opportunities to exploit the currency markets in order to improve returns, in UK terms, of their UK investors.

Given the regulatory structure relating to off shore based CTA's, the purpose of this chapter is to investigate whether investments in US$ based Managed Futures can be effectively hedged and enhanced with the use of Active Currency Management strategy. Active Currency Management concerned in this chapter is constructed as a means of

[3] A sample copy of a risk disclosure document of an UK based Managed Futures firm, Winton Capital Management, specialising in diversified Managed Futures program, is available upon request.

protecting and/or enhancing gains from a UK internationally diversified portfolio by having the ability to include Managed Futures in the portfolio.

This study focuses on studying equity portfolios that use Managed Futures and which also adopt an Active Currency Management approach to the foreign currency exposure. The remainder of the Chapter is organized as follows. Section 6.1 presents our literature review. Section 6.2 describes the data and explains the methodology. Section 6.3 discusses the results. Finally, section 6.4 summarizes the main findings of the chapter and the implications for investors.

6.1 Literature Review of International Diversification, Currency Risk and Active Trading Strategies

Early research in the area of international portfolio diversification consistently showed that the relatively low correlation of returns among international stock markets offered superior diversification opportunities for investors. For example, Grubel (1968) makes an attempt to extend the research to include international assets. Solnik (1974) provides evidence that foreign exchange risk underlying international stock market diversification can be hedged with the level of risk significantly reduced, especially compared to international stock diversification with no hedging.

Currency risk embedded in an international stock portfolio is considered as "hedged" when a short position in the currency of the relevant foreign security is taken. For example, for UK investors investing in US stocks, the hedging position would involve the investor buying UK pounds and selling US$s. The UK investor would have to do this by buying a currency forward contract (alternatively, he may use the currency option market). If the investor takes this short position consistently over time, this forward contract hedging strategy is known as a static (or "passive") hedge. Such static hedge strategy, according to Solnik (1974), is supposedly better in reducing risk than if the investors were to transact at the currency spot market prices.

Research on Active Currency Management began in the late 1980s (for a review, see Dunis & Levy, 2002)[4]. Early work investigated whether superior risk-return outcomes could be obtained from adopting a dynamic hedging strategy in which short positions (i.e., a short position in a currency forward contract) were conditionally implemented. The primary motive of adopting such an approach stems from the fact that currencies can be viewed as a distinctive asset class. Therefore, apart from hedging international exposure, investors are more interested to see if potential profit could be attained if hedging is undertaken at the right time when persistent depreciation of the foreign currency is indicated, based on the currency hedging rules.

Such hedging strategies are largely based upon trend following rules, using techniques such as moving average[5] trading rules. Some recent examples of studies using such trading rules are Acar and Lequeux (2001) and Reinert (2000). It is not surprising that

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[4] The sequence in which the literatures review is arranged and structured follows that of Dunis & Levy (2002). Our development of the rationale and idea on using Active Currency Management is similar to that of Dunis & Levy (2002). Our focus of research however is different to Dunis & Levy (2002). These main differences will be explained later in the Chapter.

[5] Moving average is one of the most useful and objective tools available to the technical analyst. It shows the average value of an asset's price over a certain number of time periods. Moving averages aim to smooth a data series and make it easier to spot trends and smooth out price and volume fluctuations or noise that can confuse interpretation. These trends are then used to help make prediction of price movement in the near future, so that a "buy" or "sell" decision concerning the particular asset can be made. These "buy" and "sell" signals, however, are used to decide upon hedging decision for currency exposes for this chapter. Section 6.2.2 gives one example. Nevertheless, more details about the moving average as an objective tool can be found in http://www.traderslog.com/Moving-Average.htm and http://www.traderslog.com/movingaverages.htm.

foreign exchange trading rules are increasingly being used because empirical research has provided some compelling evidence that trading strategies based upon technical analysis and trend following rules could result in superior risk-return outcomes (see, for example, Taylor and Allen (1992) and Menkhoff (1997)).

There has been some published research examining the issue of using dynamic hedging approaches to deal with currency exposures and this involved applying some forms of technical trend following systems. For example, Levich and Thomas (1993a) use Active Currency Management to hedge a position dynamically in the bond market and they showed that the resulting strategy was profitable vis-à-vis the passive hedge alternative. Reinert (2000) uses a moving average based trading rule and he also demonstrates the effectiveness of Active Currency Management as compared to unhedged and passively hedged strategies.

Reinert (2000) finds that for equity portfolios with a significant international allocation (e.g., greater than 10%), Active Currency Management consistently dominates both unhedged and passively hedged strategies. Specifically, for portfolios that are well diversified across major equity markets (such as the US, UK, France, Germany, and Japan), a single technically based currency overlay strategy yields the highest risk-adjusted return as measured by the Sharpe ratio in all rolling ten-year periods and in twenty-one of twenty four rolling five-year periods over 1972-1999.

Acar and Lequeux (2001) investigate the performance of active currency programs either as an asset class or as an overlay. The authors find that managing currency exposure by replicating the currency benchmarking (known as AFX as described in the paper) via a currency fund has helped produce positive returns (net of transaction costs) over the years that are mainly due to the presence of trends in the foreign exchange markets. An Active Currency Management program has the potential to beat both hedged and unhedged benchmarks in terms of absolute and risk-adjusted returns. Acar and Lequeux (2001) consider Active Currency Management to be a form of currency fund management because in an internationally diversified portfolio, the various currencies are grouped together as a portfolio. Special allocations are then made depending on the strength of the persistence of depreciation of the foreign currency as indicated by the signal generated from the moving average trading rules. This then determines the investors' decision to hedge or not to hedge.

The profitability of particular trading rules is controversial. This is because in an efficient market, trading rules that consistently generate abnormal rates of returns should not exist. LeBaron (1992) test whether fitted linear models can replicate results from moment tests inspired by moving average technical trading rules for weekly foreign exchange series. Estimation is performed using standard OLS and maximum likelihood methods, along with a simulated method of moment's technique that incorporates the trading rule moments into the estimation procedure. Results show that linear models are capable of replicating the trading rule moments along with the small autocorrelations observed in these series. This then shows that the moving average techniques, at least those used in LeBaro (1992), appear to be well-specified and the results generated out of the moving average techniques to be reasonably stable. On the other hand, Levich and Thomas (1993b) provide evidence on the profitability and statistical significance of technical trading rules in the foreign exchange market. They utilize a new database - currency futures contracts for the period 1976-1990 - and then implement a new testing procedure based on a bootstrap methodology. The results show that simple technical trading rules have very often produced significant abnormal profits.

While researches such as LeBaron and Blake (1992) and Levich and Thomas (1993b) might have adopted relatively robust methodologies, such as simulations, to confirm profitability of currency trading rules, they do not, however, explain how such abnormal profits are possible. Arnott and Pham (1993) state that the efficiency of the foreign exchange market depends upon rational, profit-motivated investors, while the two largest participants in the foreign exchange markets - international corporations and central banks - have no direct profit motive[6]. Currency markets are therefore inefficient to some extent and the presence of central banks, often with a mandate to intervene in the foreign exchange markets to stabilize or otherwise "manage" currency fluctuations, often prevents the quick dissipation of inefficiencies.

Bracker and Morran (1999) extended the work of Arnott and Pham (1993) by empirically testing their claim regarding the profit-motivated behaviors of investors. Bracker and Morran (1999) first documents four behavioral tendencies that appear to characterize the currency markets. They then set up four trading rules based on these tendencies assuming a profit-motivated investor. The four tendencies of the currency market documented by Bracker and Morran (1999) are as follows: Firstly, the current spot price tends to do a better job of predicting what the spot price will be at a later date than does the current futures/forward price. According to Bracker and Morran (1999), this

[6]A latest survey by BIS reveals that the volume of foreign exchange dealing in April 2001 was about US$1210 billion per day. Trading between banks and non finance customers is about US$156 billion, while those between banks and financial customers are about US$329 billion. See www.bis.org.

phenomenon was first documented in Chiang (1986), with subsequent contributions, by Arnott and Pham (1993).

Secondly, interest rate differentials tend to be positively related to future changes in the currency price, i.e., currency of the high-interest rate security will tend to appreciate compared to the currency of a country with a lower interest rate. According to Bracker and Morran (1999), both Green (1992) and Arnott and Pham (1993) had previously found evidence of this pattern.

Thirdly, it is the tendency that a weak currency tends to continue to weaken, while a strong currency has a tendency to strengthen. This serial dependence is also often used as a foundation for many technical trading rules. According to Bracker and Morran (1999), this tendency had previously been documented by Kritzman (1989), Taylor (1992, 1994), and Levich and Thomas (1993).

Fourthly, it is the tendency regarding yield curve differentials. Bracker and Morran (1999) claim that Arnott and Pham (1993) and others have provided evidence that currencies in countries with steeper yield curves will tend to appreciate more compared to currencies in countries with flatter yield curves.

Bracker and Morran (1999) then explain that the rationale for these patterns stems from the fact that a significant portion of capital flows in the currency markets, both in the spot and forward markets, are not actually invested with a goal of maximizing the risk-adjusted return from currency trading. Firstly, forward prices are determined through the concept of covered interest arbitrage. Through the simultaneous purchase (selling) a currency in the spot market and selling (buying) it in the forward market, an arbitrageur can lock in a risk-free rate of interest based on the yield differentials between the interest rates in the two markets and the difference in the spot and forward currency price. Therefore, forward/futures rates are set according to this covered interest arbitrage strategy and not necessarily based on the expected spot rate at some point in the future.

Secondly, central banks buy and sell currencies in an effort to prevent sudden, dramatic price swings. Their actions are designed to dampen volatility rather than to generate profits. The activities of these two participants operating in the currency markets without a goal of maximizing risk-adjusted currency returns may present other foreign currency traders with profitable trading opportunities.

Bracker and Morran (1999) analyze these four previously documented tendencies found in the currency futures markets and develop four simple trading rules[7] based upon exploiting them. It was then found that all but one of the trading strategies generated significant profits over the full sample period from January 1978 through May 1996. The trading rules appeared to be losing their power, however, and became less profitable over the more recent time period from January 1992 through to May 1996.

To sum up, the academic literatures provide some evidence supporting the benefits of Active Currency Management to internationally diversified stock portfolios. Evidence was, however, lacking in regard to the use of Active Currency Management policies for an

[7] The Empirical Research will not explain the rules and hypothesis since they will not be referenced in details to the analysis, and therefore subsequently interest rate differential will not be considered when setting up the trading systems.

internationally diversified stock portfolio that used US$ based Managed Futures for currency hedging purposes. In the UK, Managed Futures specialists have the opportunities to exploit the OTC currency markets. Therefore, Active Currency Management will be an important issue for UK investors since US$ based Managed Futures provide a potentially suitable vehicle by which they can operationalise such strategies.

6.2 Data and Methodology

6.2.1 The Use of Data and Time Periods

The Empirical Study of this chapter assumes a UK investor holding an equally weighted portfolio consisting of the MSCI EAFE, MSCI US and the Managed Futures Indexes. Five portfolios, however, are simulated for the empirical study. Each of these individual equally weighted portfolios consists of MSCI EAFE index, MSCI US index and one of the following Managed Future indexes. They are:

1) the Trend-Follower Advisors index,

2) the Discretionary Advisors index,

3) the Financial Advisors index,

4) the Diversified Advisors index, and

5) the Currency Advisors index.

All the above market indexes[8] are computed based on Net Asset Values of all the Commodity Trading Advisors under the respective categories, on a monthly basis from 1990 to 2001. These indexes are similar to those used by The Centre for International Securities and Derivatives Markets (CISDM, see http//cisdm.som.umass.edu), on the analysis of the benefits of Managed Futures (see, for example, Cerrahoglu & Pancholi (2004)). However, when considering the use of currency data needed for the currency conversion for the UK investor, we include not only the monthly spot and forward data, but also the daily spot rates. The daily spot rate is needed to formulate the dynamic hedging rule, which provides the basis for the monthly hedging decision. The currency data are all reported in US$ per UK£. The two MSCI indexes used, the MSCI EAFE and the MSCI US, are gathered from Data-Stream International, Inc., while those of the Managed Futures indexes are gathered from the CISDM Managed Futures Benchmark series found in www.marhedge.com. All data are reported in US$.

The simple simulation exercise uses data commonly used in the industry for information and references. It therefore makes sense to restrict the use of currency to a single country. However, in a context whereby multicurrency portfolio is involved, further currency allocations are needed when considering Active Currency Management. Acar and Lequeux (2001) allocate their currencies within the equity portfolio by weighting them against the proportion of the trading volume of the currency pairs as reported by the Bank of International Settlements' triennial survey. Reinert (2000) used the underlying stock market capitalization of the country to which the currency belongs in order to determine the

[8] A summary of the Description of the main data of this chapter includes the reasons for the use of the time period for this chapter, can be found in table 3.2 of chapter 3. Section 3.2.1.2 of the same chapter explains the choice and the selection of data used in this chapter, while Table 3.4(C) provides the summary of the descriptive statistics of these data for the entire sample period.

weights to be attached to the multicurrency portfolio, while Dunis and Levy (2002) equally weighted the different currency pairs underlying their portfolios.

The UK investor of this chapter considers three currency conversion methods. They are: 1) the spot rate, 2) the forward contract, and 3) the Active Currency Management approach. We assume that UK investors allocate equal proportions of funds to each of the underlying assets in their portfolio[9].

6.2.2 Methodology of the Technical Trading System

Technical trading rules based upon moving average trend tracing methods are widely used in currency markets. Acar & Lequeux (2001) explain that the "Buy" and "Sell" signals generated by moving averages could be used to dynamically hedge the currency component of international assets. For instance, a German investor having invested in the United States might use the "Buy" signal on the Deutschemark futures contracts to repatriate the dollar investment into deutsche mark. When a "Sell" signal is generated the German investor will keep/regain his unhedged position that is implicitly short of German Marks.

Using the above method of generating "buying" and "selling" signals to guide hedging decisions, 32, 61 and 117 days are chosen as the three main moving averages orders, considering them only as individual single moving averages. Single moving average

[9] To test the viability of equally weighting our portfolio, F-Statistic is used to testify for the variability of the returns among the various groups of assets that are used in this Chapter. Like Acar & Leqeuex (2001) and Dunis & Levy (2002) who consider the allocation based on local-currency-based market capitalisation of the underlying assets of the portfolio, the returns series denominated in local currency is used for the F-test. Appendix 6.1 gives the details. The results show that there is not much difference in the variability of return series among the group of assets used within the various portfolios. This suggests that equally weighting the portfolio assets is reasonable.

is a more straightforward and efficient method when compared with triple moving or double moving averages.

One could also deal with Active Currency Management by replicating a currency benchmark that is constructed for the purpose. Both Acar & Lequex (2001) and Acar & Lequex (1998) discuss one such approach in which the correlation of moving averages of 32, 61 and 117 days were taken into account within a portfolio of currency pairs of GBP/USD, USD/CHF, USD/YEN, USD/DEM, GBP/DEM, DEM/CHF and DEM/YEN. One other reason why we have chosen 32, 61 and 117 days is because these moving windows appear to be both popular and effective when used as Active Currency Management benchmarks in the industry – see again, Acar & Lequex (2001) and Acar & Lequex (1998).

The hedging criteria adopted in Reinert (2000) will be used in this chapter, as the basis for generating the "buy" or "sell" signals, for hedging decisions. The first criterion is when the spot exchange rate exceeds the moving averages. The second criterion is when the monthly spot rate closing value exceeds the daily average spot rate (calculated at the end of the month on the same day as the monthly spot rate closing value is reported).

Three different moving average methods are used to generate the "buy" and "sell" signals. Each of them will use the 32, 61 and 117 day to compute the moving averages of the price that will be used to generate the "buy" and "sell" signals. They are: the Linearly Weighted Moving Average (thereafter "LWMA"), Exponential Moving Average (thereafter "EMA") and the Simple Moving Average method (thereafter "SMA"). While the SMA simply averages out the prices in the past n days of the asset, LWMA average places more weights on more recent prices, while EMA put more weighting on earlier prices. The following provides a brief description of each of these three moving average methods.

6.2.3 Methodology of Computing the Moving Averages

6.2.3.1 Simple Moving Averages (SMA)

The SMA of n days is the arithmetic average of the closing prices of an asset during the last n days. Denote by P_t the closing price at day t, P_{t-i} the closing price at day t-i and MA_{tn} the n day moving average at day t. The simple moving average of n days is defined as:

$$MA_{tn} \equiv \frac{\sum_{i=0}^{n-1} P_{t-i}}{n}$$

6.3.3.2 Linearly Weighted Moving Averages (LWMA)

The LWMA of n days is the weighted average of the closing prices of an asset over the last n days. The LWMA assigns weights to the price series so that the more recent prices have larger weights. Denote by WMA_{tn} the n-day linearly weighted moving average at day *t*. The LWMA is defined as:

$$WMA_{tn} \equiv \frac{\sum_{i=0}^{n-1} (n-i) * P_{t-i}}{\sum_{i=0}^{n-1} (n-i)}$$

6.2.3.3 Exponential Moving Averages (EMA)

The EMA assigns weights in a slightly different manner. The most recent price is assigned a weight of $\frac{2}{(\text{Number of days}+1)}$, denoted by "a". Instead of calculating weights for all previous prices, however, it simply takes the previous day's exponential moving average and multiplies it by (1-a). Denote by EMA_{t-1} the exponential moving average at day t-1, by "n" the number of days chosen for averaging and by "a" the result of $\frac{2}{(n+1)}$. The n-day exponential moving average at day t, EMA_{tn} is given by:

$$EMA_{tn} \equiv a * P_t + (1-a) * EMA_{t-1}$$

6.2.4 Methodology for the Currency Conversion that use the Spot Rates, Forward Contracts and the Active Currency Management approach

The following presents the computation in relation to the hedging decision. Denote by R the monthly US$ rate of return of the MSCI North America, MSCI EAFE or the Managed Futures indexes, by F the forward rate; by S the spot rate; by e the monthly returns[10] of the spot rate; by f the forward premium[11] for the US$ invested in the North America index, EAFE index or the Managed Futures index. The following defines the three

[10] As the exchange rate is quoted as US$ per UK£, the monthly returns of spot rates is computed as: $\frac{S_{t-1}}{S_t} - 1$.

[11] Forward premium is defined as: $\frac{F}{S} - 1$.

methods and the currency conversion that use the spot rate, the price of the forward contract and the Active Currency Management.

UK£ returns using the spot rate market

$$R_{£}^{e} \equiv (1+R)(1+e)-1 \qquad (6.1)$$

UK£ returns using the one month currency forward contract

$$R_{£}^{f} \equiv (1+R)(1+f)-1 \qquad (6.2)$$

Using Active Currency Management

$$R_{£}^{A} \equiv \begin{cases} (1+R)(1+f)-1 & \text{if} \quad MA_{z} < Y_{lk} \le \sum_{l=1}^{N} \frac{X_{l}}{N} \\ (1+R)(1+e)-1 & \text{Otherwise} \end{cases} \qquad (6.3)$$

where,

MA_z = Moving average where z indicates the type of moving average,

z =1, refers to simple moving averages,

z =2 refers to linearly weighted moving averages, and

z =3 refers to exponential moving averages.

Y_{lk} = End of month spot rate, with $l = 1$ to 12 and $k = 1990$ to 2001 for the years that are involved.

$\sum_{a=1}^{N} \frac{X_a}{N}$ = Spot rate monthly average, X_a is the daily spot rate, and N is the number of days in the month where spot rates are reported.

6.2.5 The Portfolio Asset Allocation considering Currency Conversion Methods

$R_{£p}$ denotes the return on all equally-weighted portfolios of the MSCI EAFE, North America and Managed Futures indexes over time *t*. Individual indexes are denoted by the subscript *i*, with i = 1 for MSCI EAFE; *i* = 2 for MSCI North America and *i* = 3 for Managed Futures. The portfolio returns using each of the three currency conversion methods is as follows:

$R_{£p}{}^{e} = \frac{1}{3}\sum_{i=1}^{3} R_{i£}{}^{e}$ using the spot rate from (6.1)

$R_{£p}{}^{f} = \frac{1}{3}\sum_{i=1}^{3} R_{i£}{}^{f}$ using the forward contract from (6.2)

$R_{£p}{}^{A} = \frac{1}{3}\sum_{i=1}^{3} R_{i£}{}^{A}$ using the Active Currency Management approach from (6.3)

This analysis uses data from 1990 to 2001. Observations during 1990 are put aside for estimating the first values for the moving averages[12]. As the analysis aims to compare the results on a full 12-months yearly basis, the computation therefore starts from the beginning of 1991. Active Currency Management entails that once a signal is generated, we use it for the coming month, be it hedge or un-hedge, and this process is then repeated monthly until November 2001, in which the decision to hedge or un-hedge will be decided for the month of December 2001. The monthly returns are then computed by compounding

[12] The whole of 1990 is not fully used up since the longest moving average we use is only 117 days. The initial moving average is calculated, the value is then used to decide on the hedging decision for the coming one month, the returns calculated and the next moving averages computation takes place. The condition whether or not to take on hedging is stated in equation (6.3).

the returns of the past twelve months and then compare the results across the three currency conversion methods.

6.3 Discussion of Results

Portfolio returns in UK£ are computed using moving averages of 32 days (thereafter "32D"), 61 days (thereafter "61D") and 117 days (thereafter "117D") for Active Currency Management, together with the spot rate and forward contract as the currency conversion methods for a UK equity portfolio that uses Managed Futures. The portfolio returns are monthly compounded annual returns from 1991 to 2001, and are computed for each of the three currency conversion methods mentioned above.

Figures 6.1 to 6.3[13] [14] [15] provide basic descriptive statistics (i.e., the mean values, the standard deviation, the maximum values, minimum values and skewness) of the portfolios' annual returns over the 11 years from 1991 to 2001. The comparison is made across different currency conversion methods, i.e., the Active Currency Management approach (where we further divide them into SMA, LWMA and EMA), the spot rates and the forward contracts for equity portfolio using the various types of Managed Futures.[16]

[13] Figures 6.1 to 6.3 and Figures 6.4 to 6.5, which will be discussed later, are all compiled towards the end of the chapter.
[14] In each of the figures, 6.1, 6.2 and 6.3, there are 5 graphs each representing a specific portfolio, such as EAFE/North America/Discretionary, EAFE/North America/Trend CTA, etc. Figure 6.1 shows the case for 32D; Figure 6.2 shows the case for 61D and Figure 6.3 for 117D.
[15] See Appendix 6.2A, 6.2B & 6.2C to 6.4A, 6.4B & 6.4C for comparing the full 11-years annual compounded returns from 1991 to 2001. These compounded returns are compared across the different currency conversion methods, i.e., the Active Currency Management, the spot rate and the forward contract.
[16] Statistical t test is conducted to investigate the similarity of the monthly returns generated by the various Managed Futures used within the equity portfolios, across spot rate, forward contracts and Active Currency Management. The results show that the monthly returns are significantly different at 5% level (critical value 1.969) from each others when using Active Currency Management, spot rates and forward contracts. The p values (t-statistics) are between 0.00034709 (4.913) and 0.02252 (2.295).

The evidence in the figures suggests that equity portfolios that use Managed Futures and Active Currency Management produce positive average annual returns over the 11 years from 1991 to 2001. Among the portfolios that use Active Currency Management, the highest annual minimum portfolio return is 6%, obtained by the equity portfolio that uses Diversified CTA and implements a 61D SMA. The lowest annual minimum portfolio return is about -6%, obtained by the equity portfolio that uses 117D EMA and Currency CTA. Amongst all portfolios, the lowest annual minimum portfolio return is about -21.8% obtained by the equity portfolio that uses Diversified CTA and spot rates. Amongst portfolios that use the forward contract conversion method, the lowest annual minimum portfolio return is about -16.3% obtained by the equity portfolio that uses Finance CTA.

Using Active Currency Management and Managed Futures for equity portfolios also produces higher annual maximum portfolio returns. The highest annual maximum return of 77% is obtained by the equity portfolio that uses Currency CTA, 32D and SMA for Active Currency Management. However, equity portfolios using Finance CTA and either the spot rates or the forward contracts only managed a maximum of approximately 28%.

Descriptive statistics from Figures 6.1 to 6.3 also show that using Managed Futures and Active Currency Management within an equity portfolio benefits UK investors by producing portfolio returns that are positively skewed. This means that the series of returns produced would tend to be concentrated around or higher than their mean values. However, using Managed Futures and adopting spot rates or forward contracts as currency conversion methods do not benefit UK investors in a similar way. As seen in Figures 6.1 to 6.3, they tend to produce negatively skewed portfolio returns. This implies that the series of returns tend to be concentrated below mean values of portfolio returns and in some cases, as shown by the minimum portfolio returns statistics in Figure 6.1 to 6.3, they even produce negative returns. Using Managed Futures and Active Currency Management within an equity portfolio, however, produces negatively skewed returns in some cases, but only as low as -0.5 (obtained by the equity portfolio using Diversified CTA and 117 EMA as Active Currency Management). This is not as high in magnitude as -0.895, which is the case of equity portfolio using Diversified CTA and spot rates. Therefore, the return series produced by Managed Futures and Active Currency Management for equity portfolios are not as low as those of portfolios that use CTA and spot rates or forward contracts.

Figure 6.4 provides a summary comparison of the average over 11 years across the various portfolios. The comparisons show that Managed Futures and Active Currency Management produce average annual returns between two and four times higher than when the spot rates or forward contracts are used.

Using Discretionary CTA and adopting 32D SMA for Active Currency Management within equity portfolios produces the highest average annual portfolio returns of 31.4%. Using Discretionary CTA within equity portfolios also produces the highest average annual portfolio returns, among all CTAs, when spot rates and forward contracts are used. However, it only managed to produce 7.8% for spot rates, and 9.4% for forward contracts. Figure 6.1 to 6.4 provides supportive empirical evidence on the effectiveness of using Managed Futures and an applying Active Currency Management on equity portfolios for UK investors.

The years 2000 and 2001 are the two most volatile years among all the 11 years considered for our analyses. Market volatility had increased towards the end of the 1990's, especially subsequent to events such as the collapse of the technology stock prices and the September 11th crisis that took place in 2000. The empirical analysis takes that into account and the annual compounded returns are computed for the various portfolios that use the three currency conversion methods in 2000 and 2001. The aim is to examine whether using Active Currency Managements and Managed Futures still makes a difference to UK equity portfolio during these two volatile time periods. The results are reported in Figure 6.5.[17]

Figure 6.5 shows that both spot rate and forward contract strategies produce negative returns in 2000 and 2001, ranging between -12% and -16%, for equity portfolios using Managed Futures. However, the figure also shows that most of the equity portfolios that used Managed Futures and Active Currency Management had positive returns in 2000 and 2001. Using Active Currency Management of 32D SMA, 32D LWMA and 61D LWMA helped equity portfolios that used Diversified CTA to return 6.3%, which is the best positive return in 2000. While in 2001, using the Discretionary CTA strategy within the equity portfolio resulted in the highest return that year of 8.8% when an Active Currency Management strategy of 32D SMA is implemented.

The empirical findings also reveal that using Active Currency Management and Managed Futures does not always produce positive returns for equity portfolio in either 2000 or 2001. For example, using 32D LWMA in 2001 produced almost a zero return when applied to equity portfolios that used Finance CTA and Currency CTA strategies. Negative

[17] Each graph of Figure 6.5 shows the performance using the moving averages of 32D, 61D and 117D separately, with each of the moving average days compared with the spot rates and the forward contracts.

returns, however, are more substantial in the case of using 117 EMA for Active Currency Management in 2001. They range from -4.3% to -6%. Such negative returns, however, are much lower in magnitude compared with the same portfolios but with spot rates or the forward contracts for currency conversions. They are as high as -14% for the spot rates and -16% for the forward contracts.

The results in Figure 6.5 also show that the variation in the data-set might not have been captured as best as it should be by LWMA and EMA. For example, the 117D SMA and 117D LWMA in 2000 used for Active Currency Management generate the same returns for each and every Managed Futures that is used within the equity portfolio. The same case also repeats in 2001 for 117D SMA and 117D LWMA. The same pattern is also found in 61D SMA and 61D EMA for the year 2000. This shows that the same signals are generated by the moving averages that use LWMA or the EMA such that they produce the same returns.[18] There is obviously an issue of trading function specification underlying these returns. To more accurately capture the variations of returns underlying the distribution patterns of the time series of the data-set, would require further investigation and refinement of the specifications of the trend following moving average trading functions.

[18] This observation is also supported by the F-test that investigates the performance difference of using the different moving averages for the portfolios that used the various different CTAs. The critical values for testing the differences are 2.66 (5% level significance) and 3.9 (1% level significance). However, the p values (F Statistics) for the test range from 0.437 (0.828702) to 0.9942 (0.005805). The results therefore show that there are no significance differences for all 32D, 61D and 117D adopting SMA, LWMA and EMA, when applied to the various CTAs used within the equity portfolios.

In short, Figure 6.5 provided further evidence to support the superiority of using Active Currency Management to capture returns for equity portfolios that already use Managed Futures, even during periods of global financial market volatility.

6.4 Concluding Remarks

The main purpose of this chapter hais been to present an analysis of the relative benefits associated with different strategies for converting US$ denominated Managed Futures and other asset returns into UK£ portfolio returns. More specifically, we have investigated the effect upon UK investor returns of adopting either a passive or Active Currency Management approach to the conversion of US$ returns into UK£ denominated investor returns. The focus of this analysis concerns the incremental benefits to UK investors of adopting an Active Currency Management when converting their US$ portfolio (that include Managed Futures) returns into UK£ portfolio returns relative to using purely spot rate conversions (a no-hedge passive strategy) or forward contracts (a fully hedged passive strategy).

The main aim of our Active Currency Management analysis was to investigate the financial benefits stemming from a strategy in which short positions for hedging foreign currency exposure (i.e., going for a short position in a currency forward contract, selling foreign currency and buying UK£ contract) were conditioned on a hedging rule that anticipated a depreciation in the particular foreign currency (or the appreciation of the home currency). The results suggest that there are significant incremental benefits accruing to UK investors from the use of a relatively simple Active Currency Management strategy.

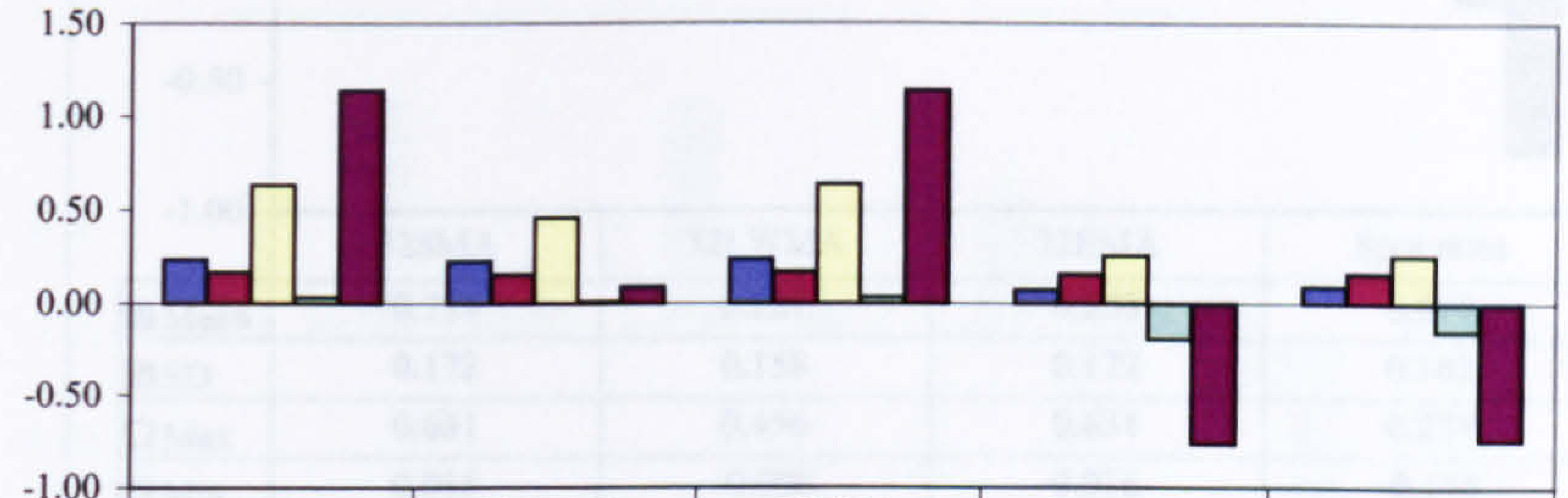
As detailed earlier in the chapter, there is a lack of published research into the use of Active Currency Management policies in respect of an internationally diversified stock portfolio for UK investors, that used US$ based Managed Futures in their portfolios. This is an important issue following the increasing use of Managed Futures as an asset class; especially in the context of an off shore foreign currency investing vehicle where managing currency exposure will naturally be a concern for UK investors.

Several studies have, however, concluded that profits are attainable when hedging is undertaken at the right time when a persistent depreciation of the foreign currency is indicated on the basis of currency hedging rules. The source of the profits obtainable from active currency investing using technical trend following rules is believed to have stemmed largely from the existence of major market participants, primarily central banks, whose main objective when trading is not to make profits but to reduce "unnecessary" fluctuations in their currency's external exchange value. The smoothed trends that result from these behaviors thereby provide opportunities for profit takers, see, for example, Bracker and Morran (1999).

A single moving average trading system is applied using the moving average order of 32, 61 and 117 days as found in Dunis and Levy (2002) and Acar and Lequeux (2001) for our empirical studies, which use data from 1991 to 2001. The findings reveal that, comparing portfolios that use Managed Futures across currency conversions methods that use spot rates, forward contracts and the Active Currency Management approach, those portfolios that used Active Currency Management performed far better than those using either solely the spot rates or forward contacts. By considering separately the performance of 2000 and 2001, where the financial markets were particularly volatile, using the spot rate and the forward contract produced negative incremental returns for equity portfolios using Managed Futures. However, almost all portfolios that used Managed Futures produced positive returns in 2000 and 2001, when applying Active Currency Management. This provides evidence that an Active Currency Management policy with respect to equity portfolios that also contain some proportion of Managed Futures is capable of producing both higher and more stable returns, especially during volatile periods.

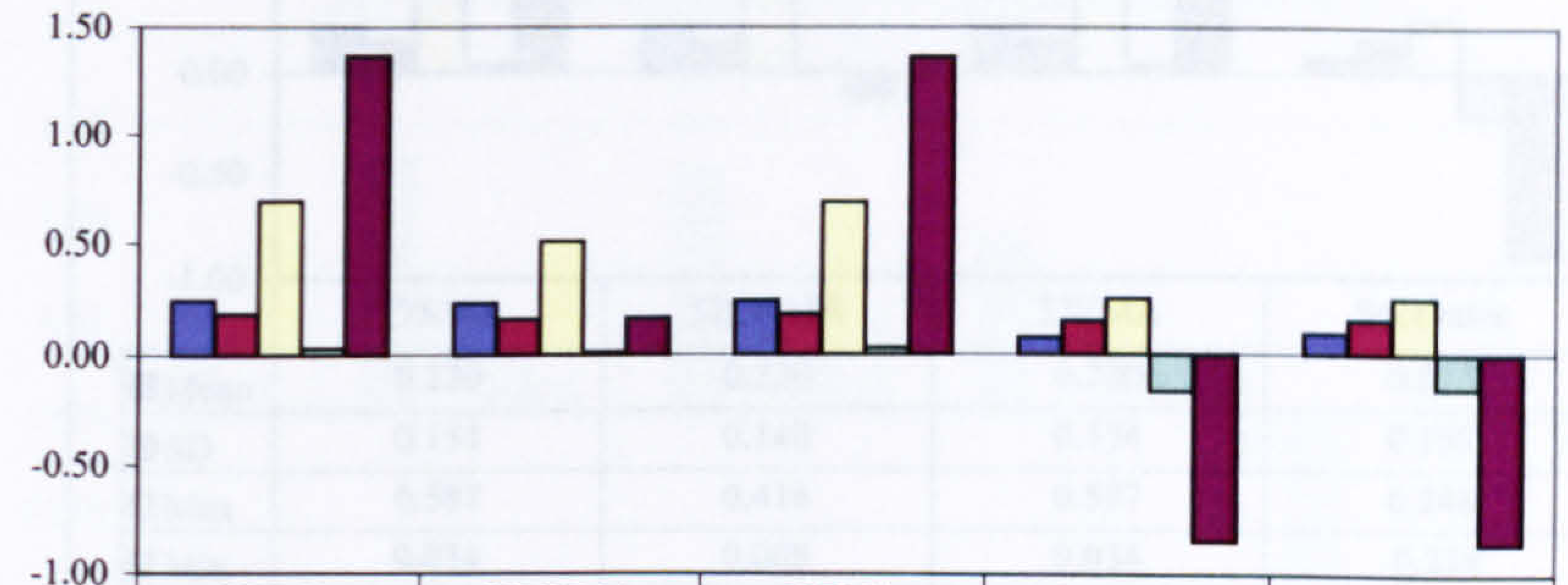
However, future research could be undertaken in respect of analyzing alternative specifications of the moving average function and to test the robustness of the results since the findings reveal that several of the moving average orders give rise to the same signals, and produce similar returns, as shown in Figure 6.5. In any case, further research exploring the pattern of the data and the use of a more well- specified model for the moving average functions is needed to determine the robustness of the results obtained in this chapter.

Figure 6.1: Comparison of the descriptive statistics of the annual compounded equally weighted portfolio returns (consist of MSCI EAFE, MSCI North America and the Managed Futures indexes) across different currency conversion methods of 32SMA, 32LWMA, 32EMA, spot rates and the forward contracts



	32SMA	32LWMA	32EMA	Spot rates	Forward
Mean	0.236	0.226	0.236	0.074	0.089
SD	0.169	0.156	0.169	0.155	0.159
Max	0.635	0.459	0.635	0.252	0.254
Min	0.033	0.010	0.033	-0.194	-0.149
Skew	1.139	0.090	1.139	-0.763	-0.744

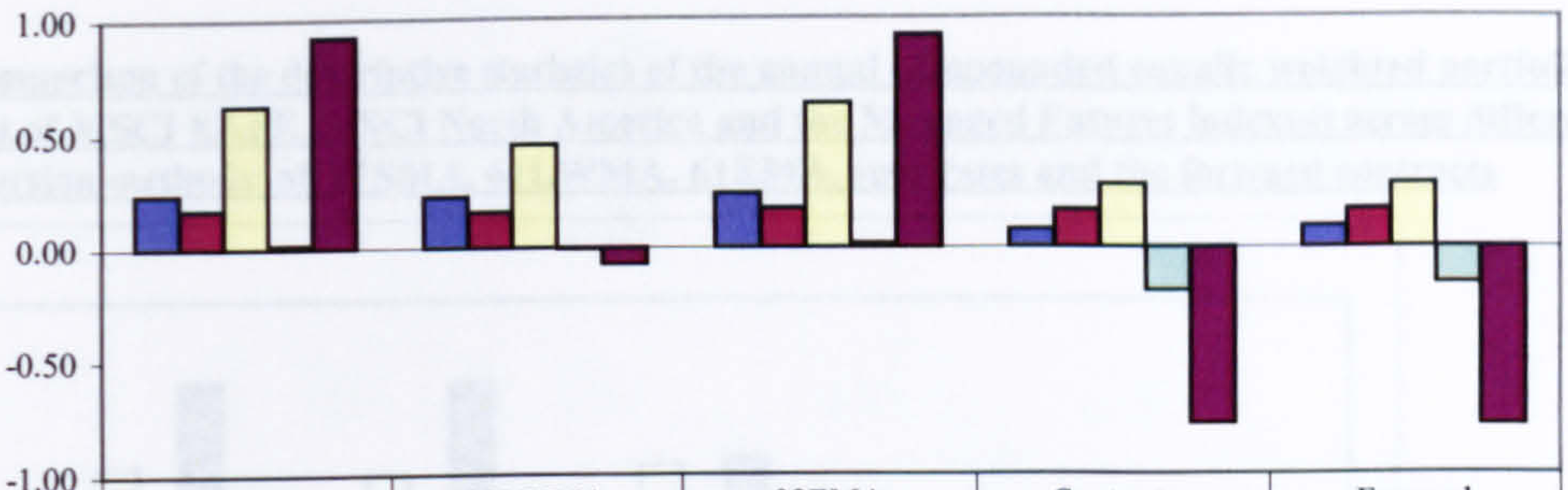
The EAFE/North US/Trend Following CTA portfolio



	32SMA	32LWMA	32EMA	Spot rates	Forward
Mean	0.243	0.232	0.243	0.078	0.094
SD	0.183	0.161	0.183	0.150	0.155
Max	0.689	0.508	0.689	0.248	0.250
Min	0.027	0.011	0.027	-0.167	-0.154
Skew	1.366	0.165	1.366	-0.847	-0.856

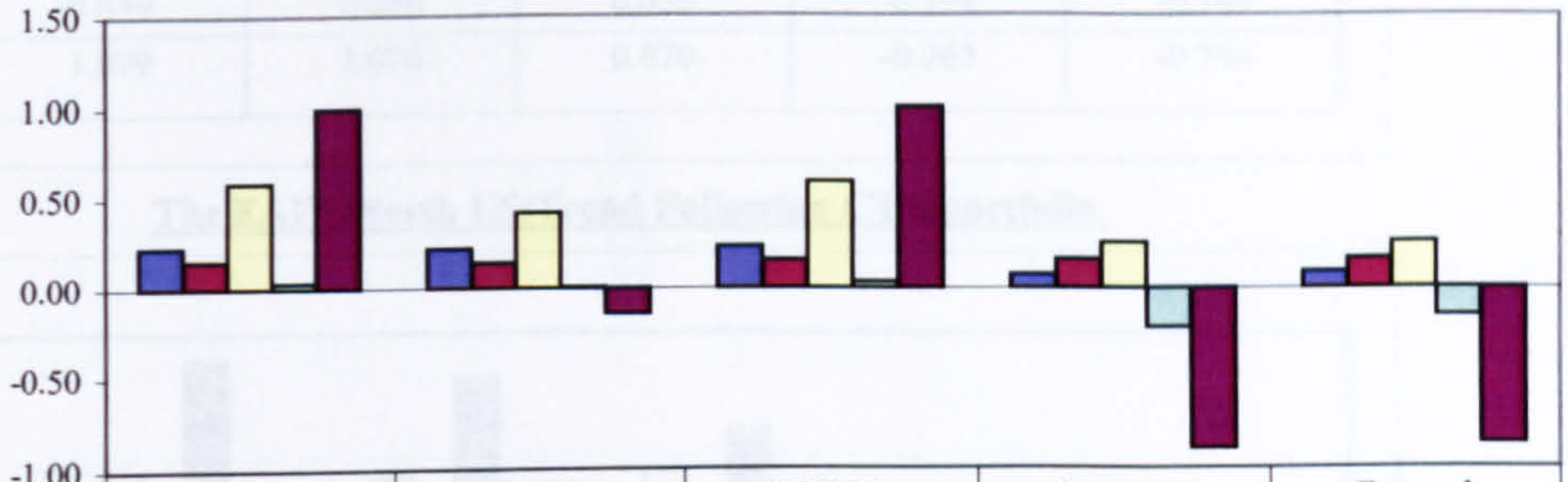
The EAFE/North US/Discretionary CTA portfolio

Figure 6.1 (Con't)



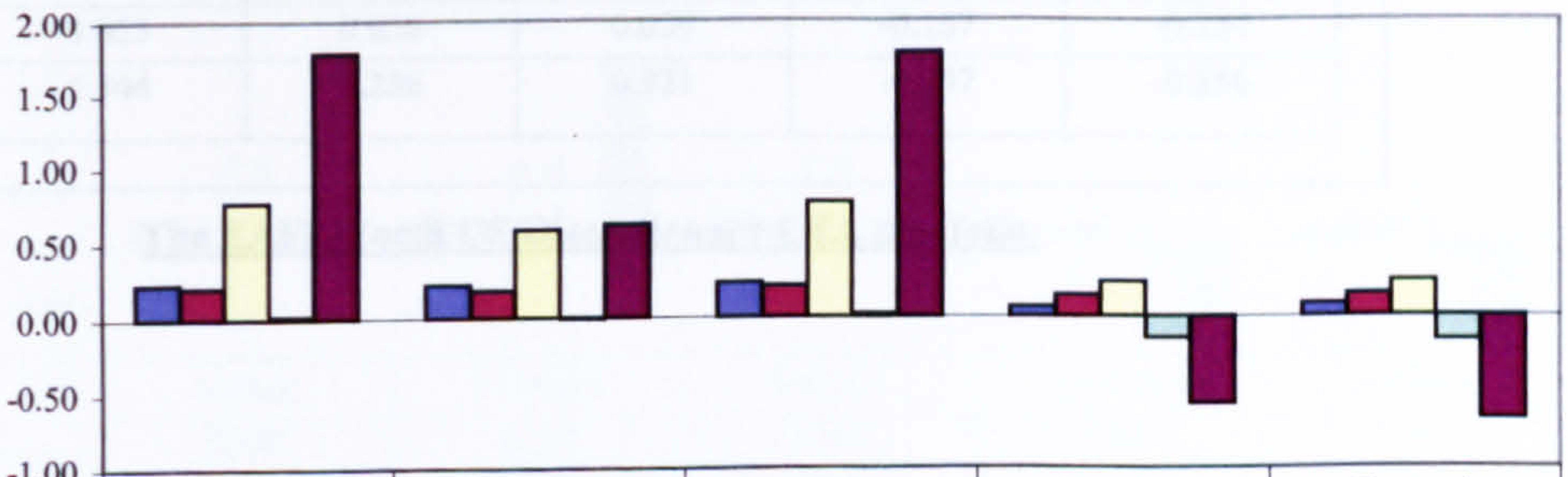
	32SMA	32LWMA	32EMA	Spot rates	Forward
Mean	0.238	0.227	0.238	0.076	0.092
SD	0.172	0.158	0.172	0.162	0.166
Max	0.631	0.456	0.631	0.274	0.276
Min	0.016	-0.006	0.016	-0.196	-0.163
Skew	0.926	-0.074	0.926	-0.782	-0.790

The EAFE/North US/Finance CTA portfolio



	32SMA	32LWMA	32EMA	Spot rates	Forward
Mean	0.230	0.220	0.230	0.071	0.086
SD	0.154	0.140	0.154	0.158	0.159
Max	0.587	0.416	0.587	0.248	0.250
Min	0.034	0.005	0.034	-0.218	-0.154
Skew	0.988	-0.144	0.988	-0.895	-0.866

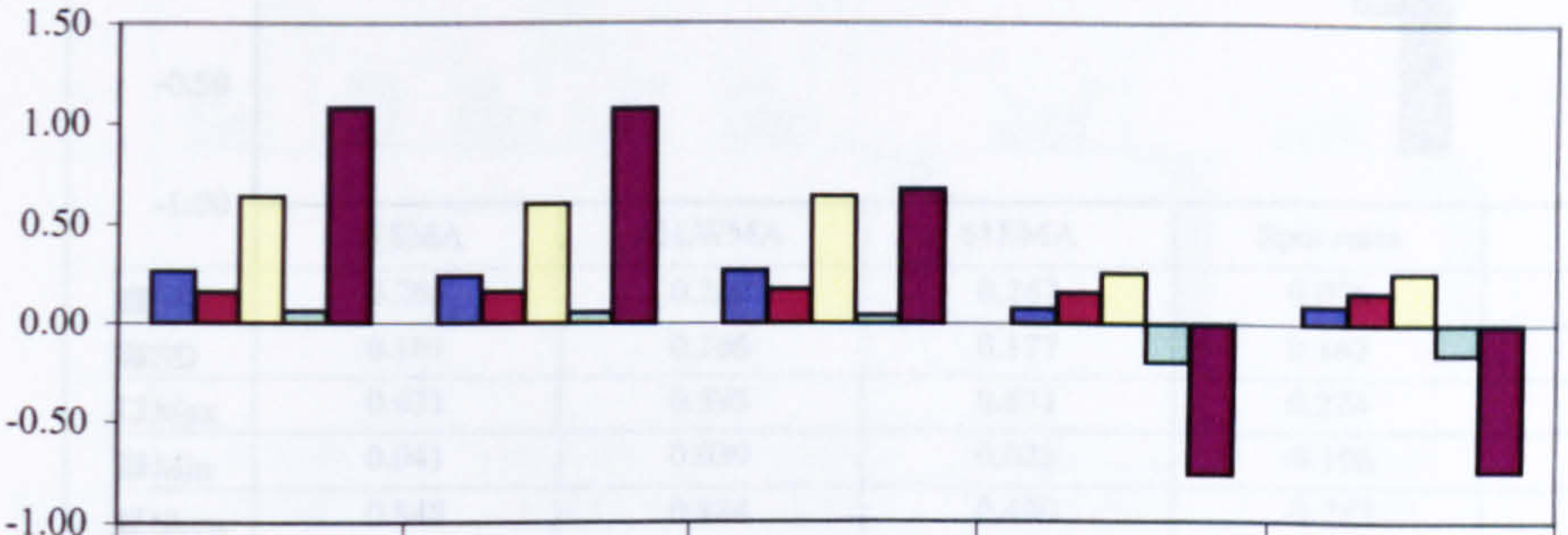
The EAFE/North US/Diversified CTA portfolio



	32SMA	32LWMA	32EMA	Spot rates	Forward
Mean	0.232	0.221	0.232	0.065	0.081
SD	0.208	0.182	0.208	0.143	0.150
Max	0.770	0.580	0.770	0.231	0.233
Min	0.021	-0.007	0.021	-0.144	-0.162
Skew	1.786	0.618	1.786	-0.576	-0.679

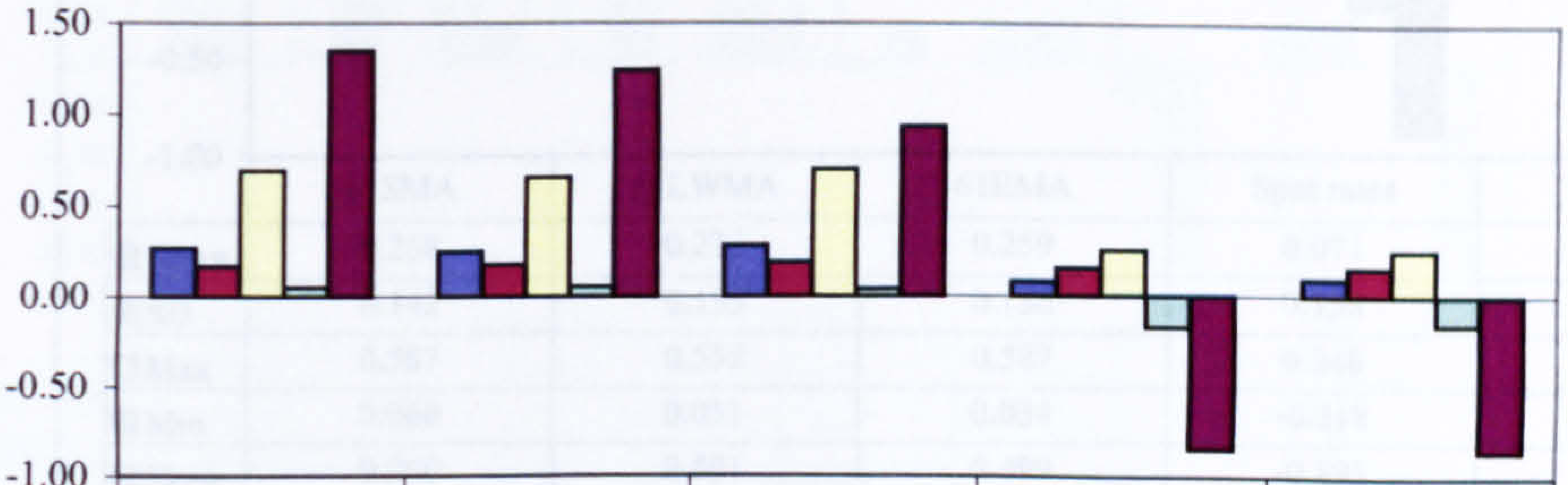
The EAFE/North US/Currency CTA portfolio

Figure 6.2: Comparison of the descriptive statistics of the annual compounded equally weighted portfolio returns (consist of MSCI EAFE, MSCI North America and the Managed Futures indexes) across different currency conversion methods of 61SMA, 61LWMA, 61EMA, spot rates and the forward contracts



	61SMA	61LWMA	61EMA	Spot rates	Forward
Mean	0.263	0.240	0.265	0.074	0.089
SD	0.159	0.162	0.175	0.155	0.159
Max	0.635	0.599	0.635	0.252	0.254
Min	0.059	0.056	0.039	-0.194	-0.149
Skew	1.079	1.070	0.670	-0.763	-0.744

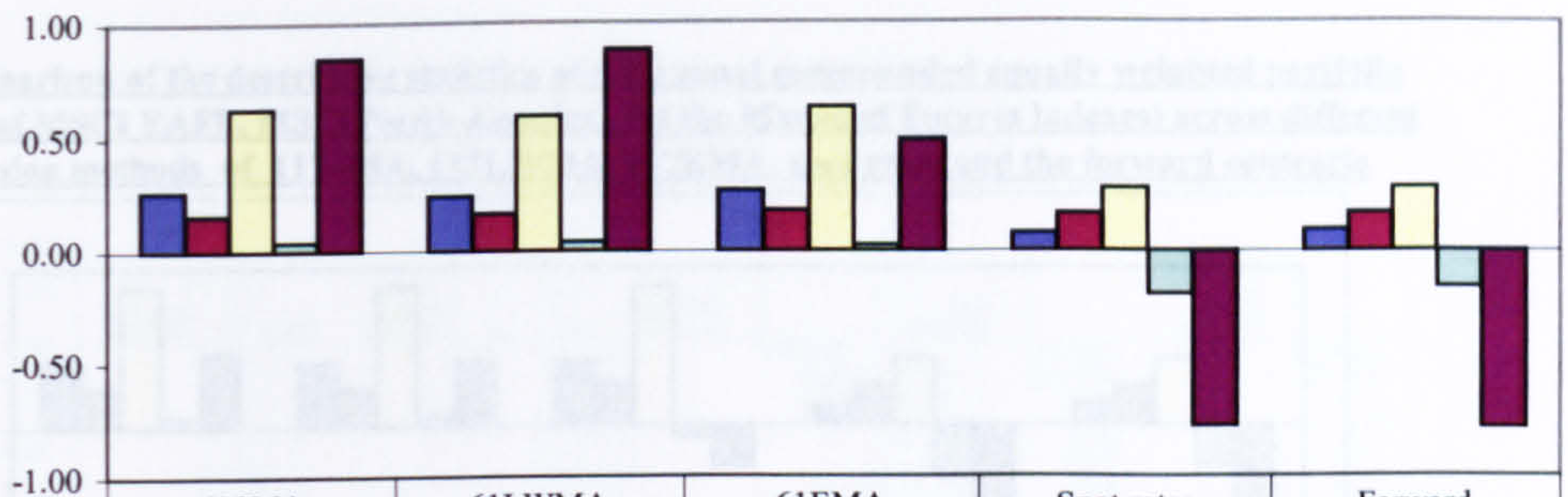
The EAFE/North US/Trend Following CTA portfolio



	61SMA	61LWMA	61EMA	Spot rates	Forward
Mean	0.271	0.248	0.273	0.078	0.094
SD	0.170	0.178	0.185	0.150	0.155
Max	0.689	0.652	0.689	0.248	0.250
Min	0.053	0.056	0.039	-0.167	-0.154
Skew	1.344	1.236	0.921	-0.847	-0.856

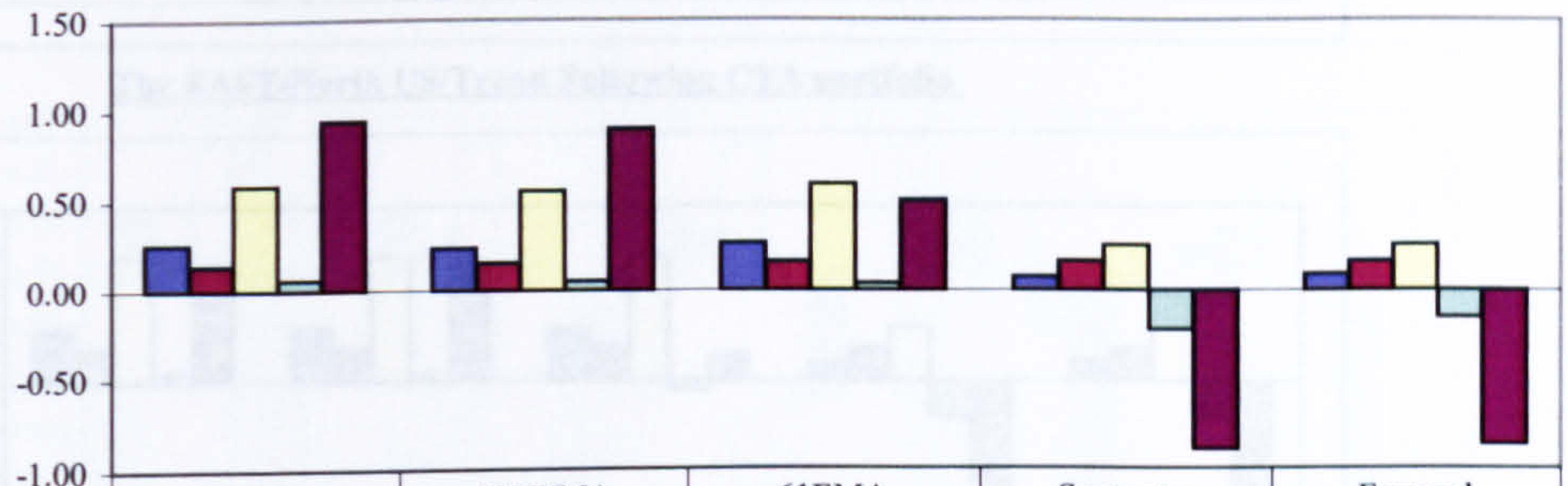
The EAFE/North US/Discretionary CTA portfolio

Figure 6.2 (Con't)



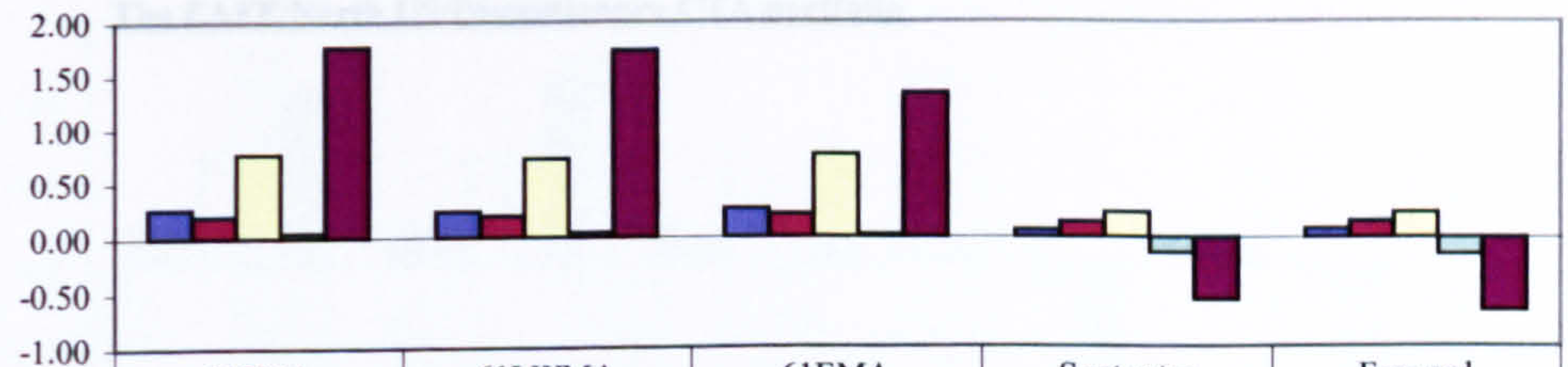
	61SMA	61LWMA	61EMA	Spot rates	Forward
Mean	0.265	0.242	0.267	0.076	0.092
SD	0.161	0.166	0.177	0.162	0.166
Max	0.631	0.595	0.631	0.274	0.276
Min	0.041	0.039	0.023	-0.196	-0.163
Skew	0.848	0.884	0.490	-0.782	-0.790

The EAFE/North US/Finance CTA portfolio



	61SMA	61LWMA	61EMA	Spot rates	Forward
Mean	0.258	0.235	0.259	0.071	0.086
SD	0.142	0.153	0.156	0.158	0.159
Max	0.587	0.552	0.587	0.248	0.250
Min	0.060	0.051	0.034	-0.218	-0.154
Skew	0.940	0.891	0.499	-0.895	-0.866

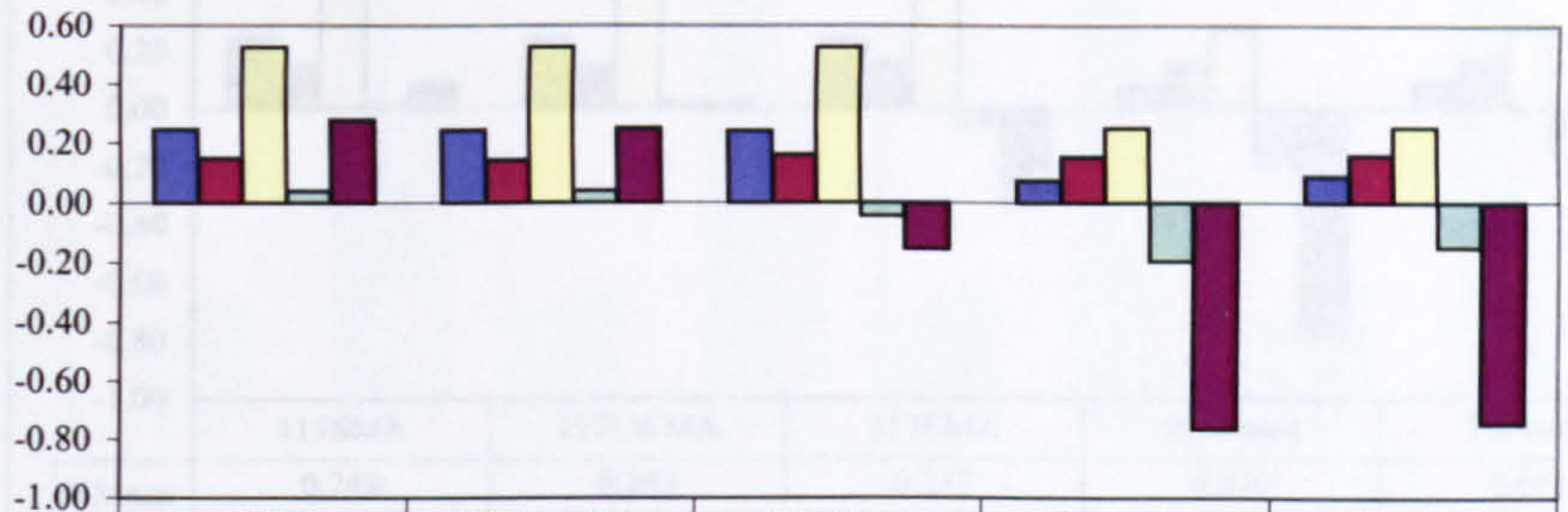
The EAFE/North US/Diversified CTA portfolio



	61SMA	61LWMA	61EMA	Spot rates	Forward
Mean	0.259	0.235	0.261	0.065	0.081
SD	0.198	0.194	0.212	0.143	0.150
Max	0.770	0.731	0.770	0.231	0.233
Min	0.047	0.038	0.021	-0.144	-0.162
Skew	1.771	1.740	1.342	-0.576	-0.679

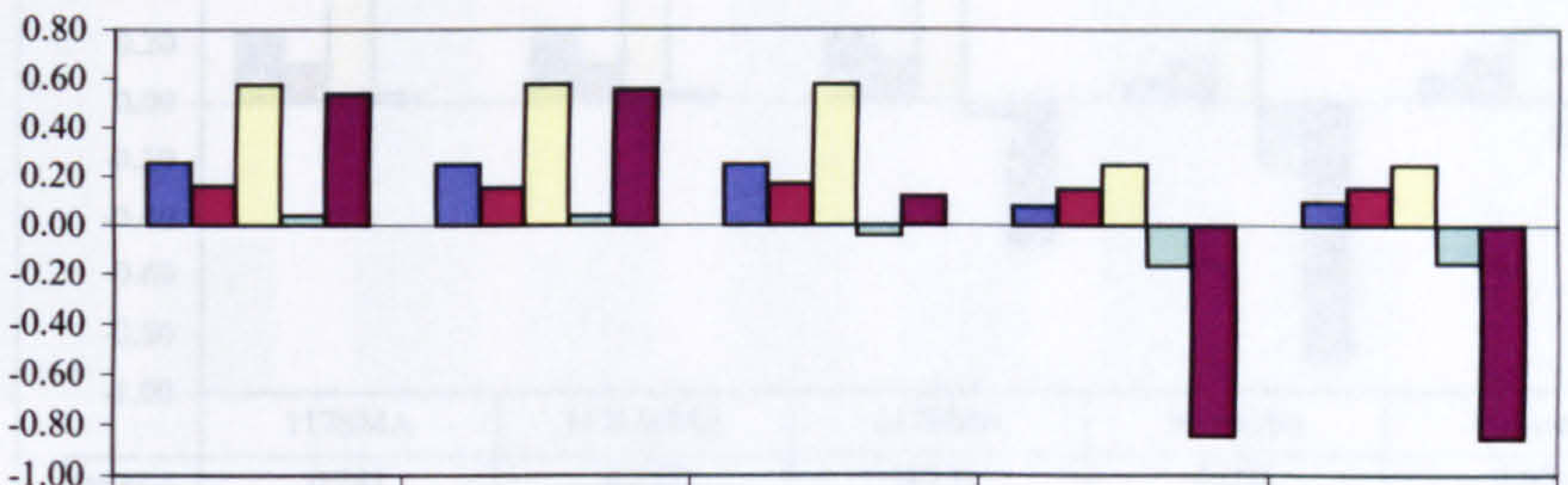
The EAFE/North US/Currency CTA portfolio

Figure 6.3: Comparison of the descriptive statistics of the annual compounded equally weighted portfolio returns (consist of MSCI EAFE, MSCI North America and the Managed Futures indexes) across different currency conversion methods of 117SMA, 117LWMA, 117EMA, spot rates and the forward contracts



	117SMA	117LWMA	117EMA	Spot rates	Forward
Mean	0.246	0.242	0.240	0.074	0.089
SD	0.148	0.142	0.160	0.155	0.159
Max	0.526	0.526	0.526	0.252	0.254
Min	0.039	0.039	-0.043	-0.194	-0.149
skew	0.278	0.250	-0.153	-0.763	-0.744

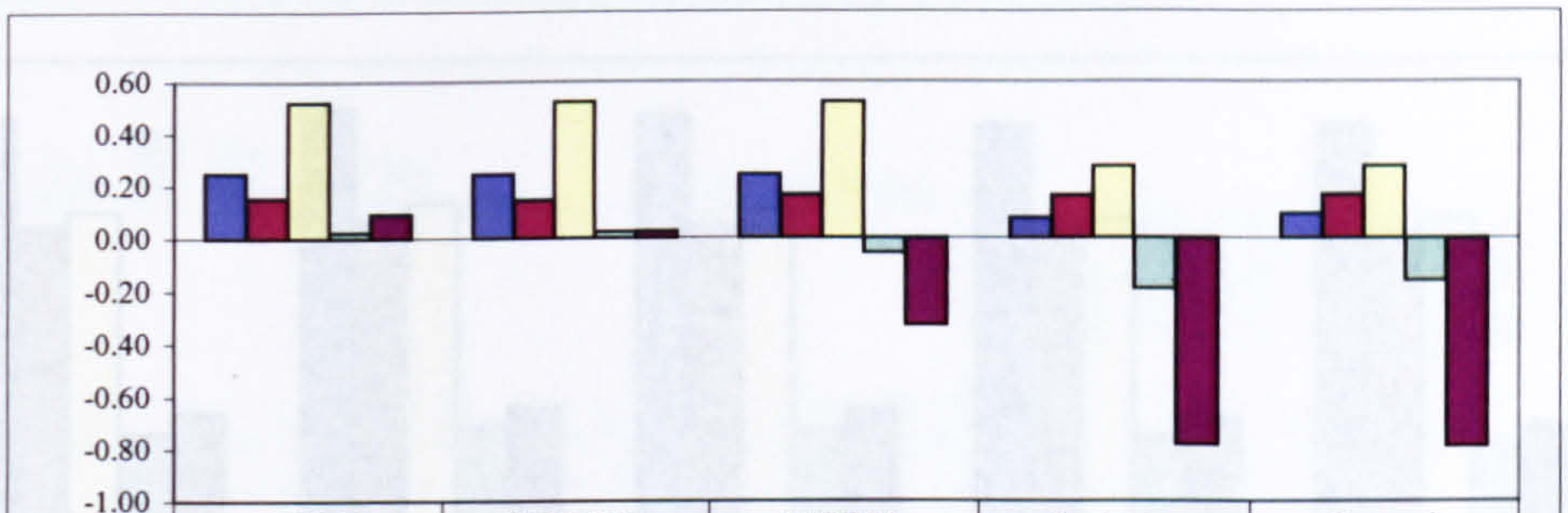
The EAFE/North US/Trend Following CTA portfolio



	117SMA	117LWMA	117EMA	Spot rates	Forward
Mean	0.253	0.249	0.247	0.078	0.094
SD	0.159	0.152	0.170	0.150	0.155
Max	0.576	0.576	0.576	0.248	0.250
Min	0.039	0.039	-0.043	-0.167	-0.154
skew	0.538	0.555	0.117	-0.847	-0.856

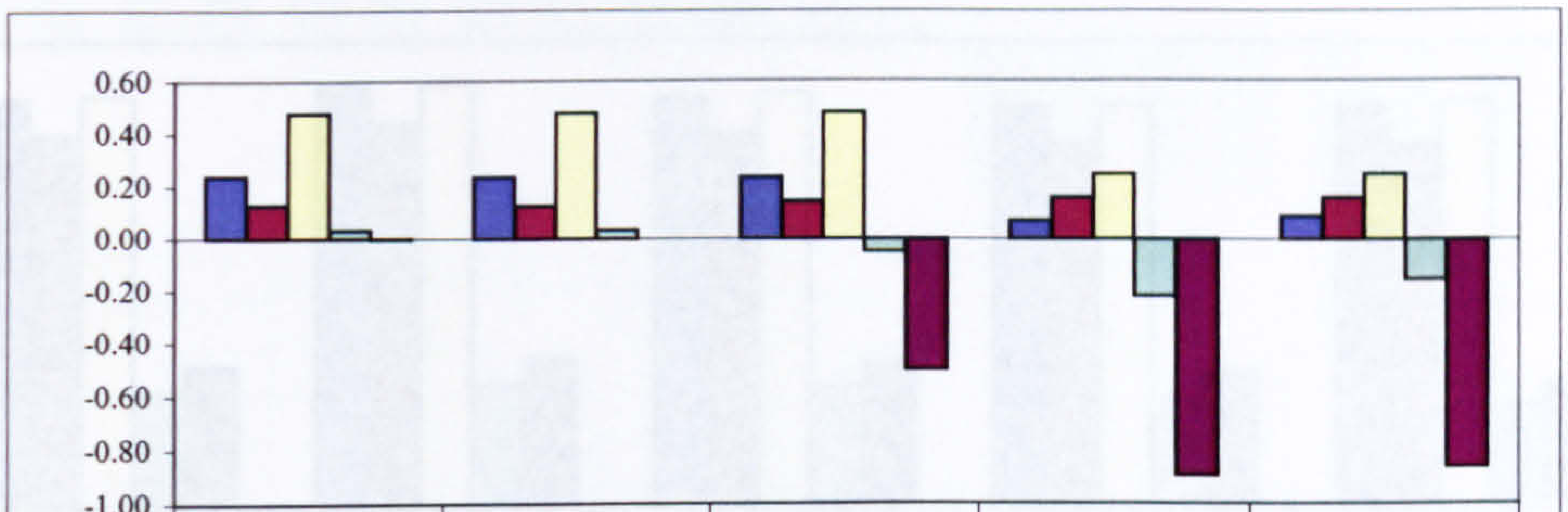
The EAFE/North US/Discretionary CTA portfolio

Figure 6.3 (Con't)



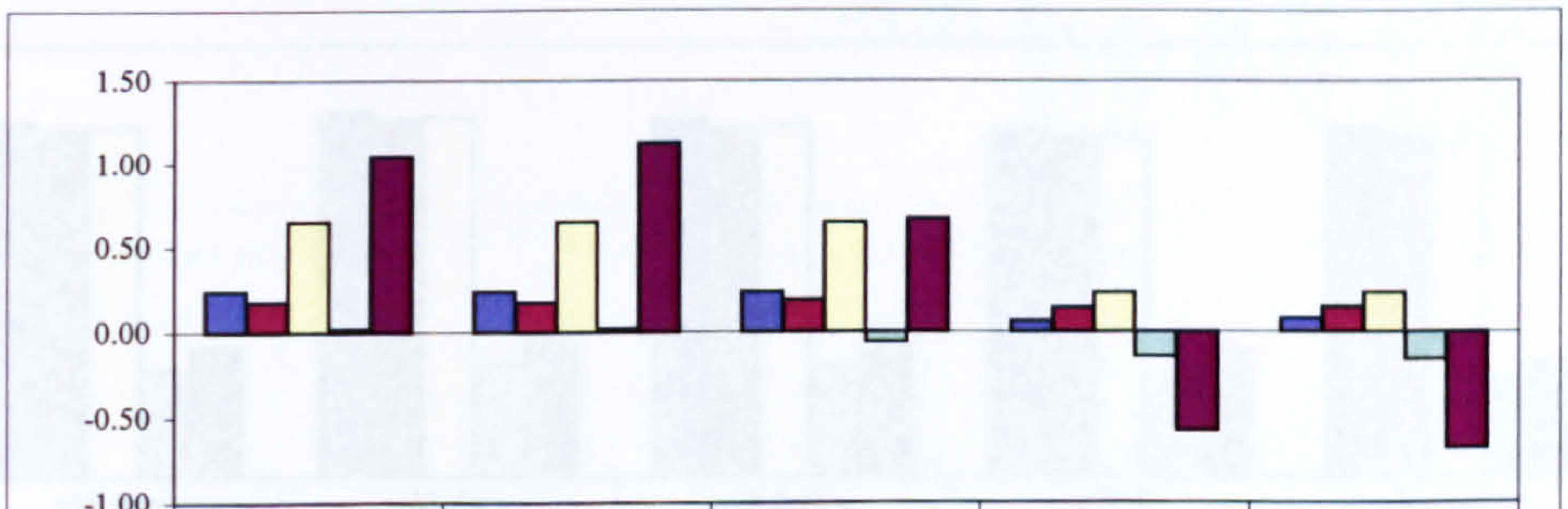
	117SMA	117LWMA	117EMA	Spot rates	Forward
Mean	0.248	0.244	0.242	0.076	0.092
SD	0.152	0.146	0.164	0.162	0.166
Max	0.522	0.522	0.522	0.274	0.276
Min	0.023	0.023	-0.058	-0.196	-0.163
skew	0.091	0.024	-0.331	-0.782	-0.790

The EAFE/North US/Finance CTA portfolio



	117SMA	117LWMA	117EMA	Spot rates	Forward
Mean	0.241	0.237	0.235	0.071	0.086
SD	0.131	0.127	0.144	0.158	0.159
Max	0.481	0.481	0.481	0.248	0.250
Min	0.034	0.034	-0.048	-0.218	-0.154
skew	-0.001	0.001	-0.502	-0.895	-0.866

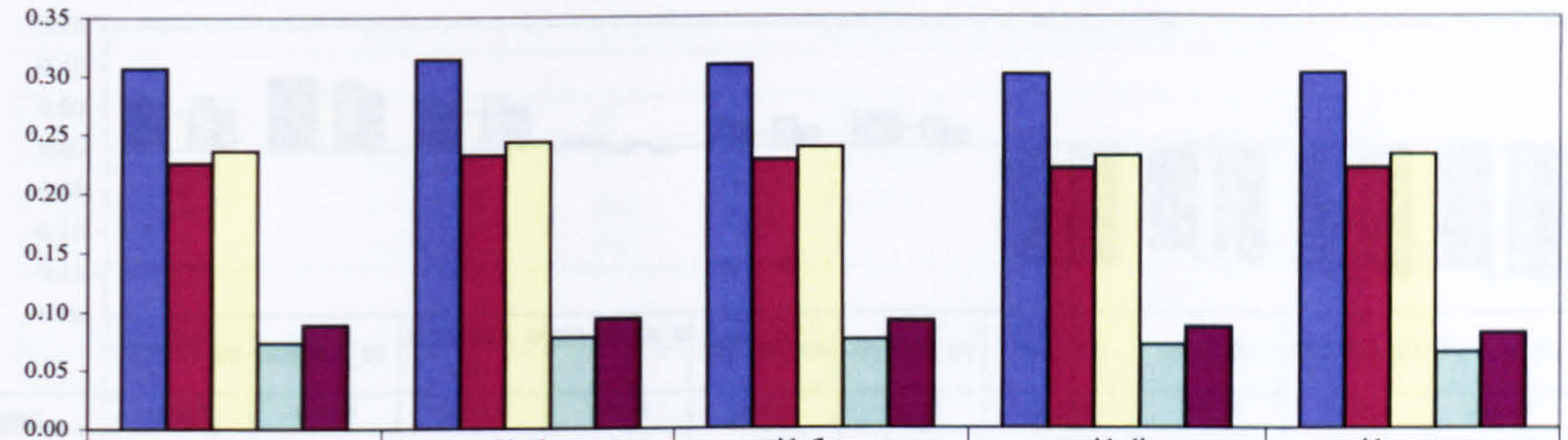
The EAFE/North US/Diversified CTA portfolio



	117SMA	117LWMA	117EMA	Spot rates	Forward
Mean	0.242	0.238	0.236	0.065	0.081
SD	0.181	0.175	0.191	0.143	0.150
Max	0.651	0.651	0.651	0.231	0.233
Min	0.021	0.021	-0.060	-0.144	-0.162
skew	1.046	1.124	0.673	-0.576	-0.679

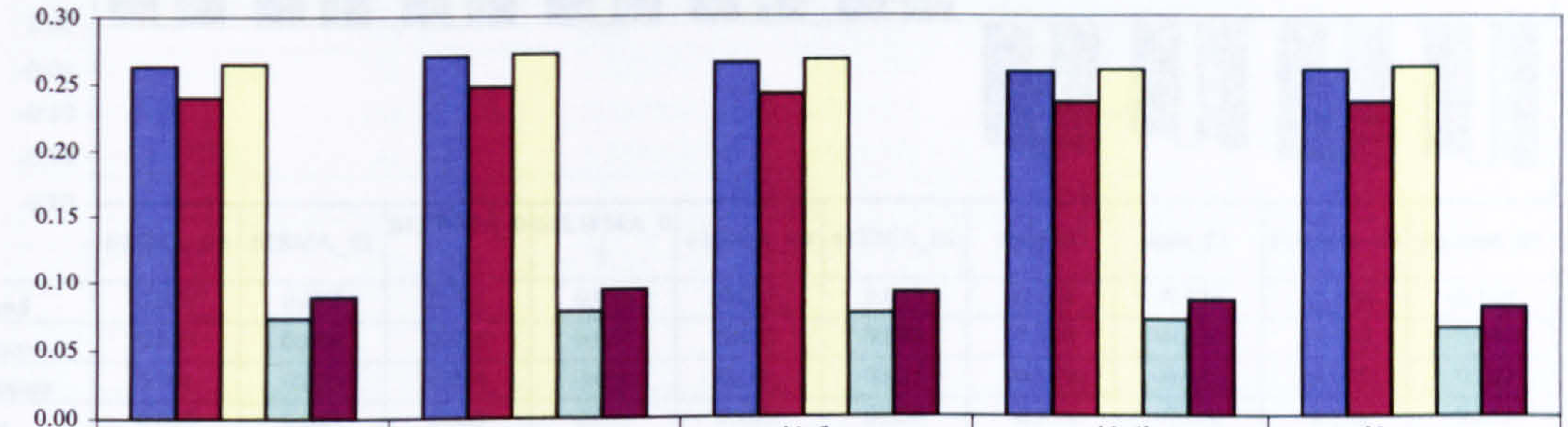
The EAFE/North US/Currency CTA portfolio

Figure 6.4: Comparison of the average annual compounded returns for the 11years from 1991 to 2001 for the equally weighted portfolios consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes.



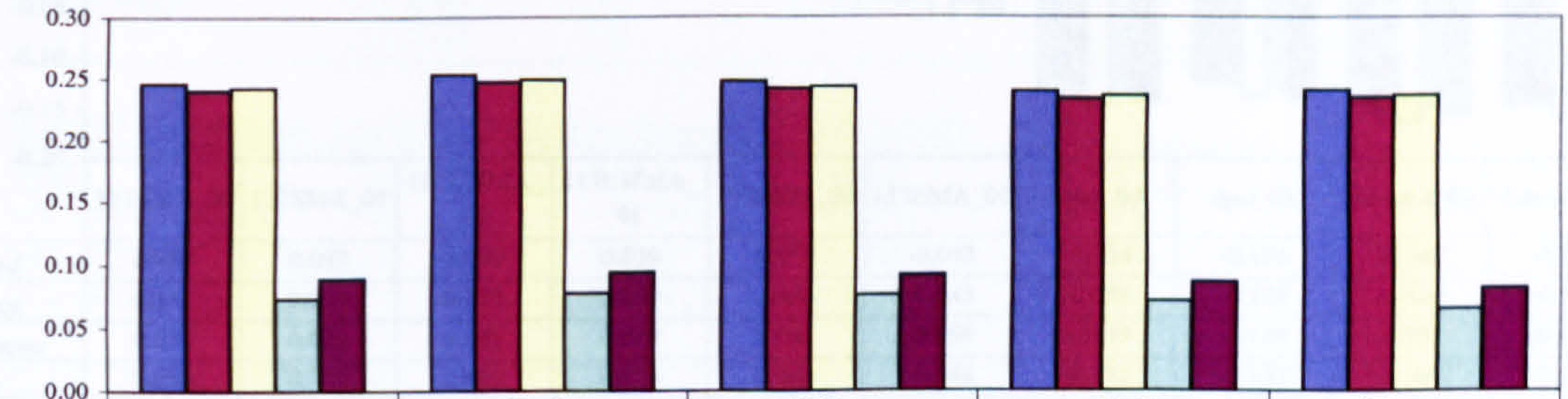
	with trend	with discn	with finance	with div	with currency
32SMA	0.307	0.314	0.309	0.301	0.302
32LWMA	0.226	0.232	0.227	0.220	0.221
32EMA	0.236	0.243	0.238	0.230	0.232
Spot	0.074	0.078	0.076	0.071	0.065
forward	0.089	0.094	0.092	0.086	0.081

Comparison across 32D SMA, 32D LWMA, 32D EMA, the spot rates and the forward contract



	with trend	with discn	with finance	with div	with currency
61SMA	0.263	0.271	0.265	0.258	0.259
61LWMA	0.240	0.248	0.242	0.235	0.235
61EMA	0.265	0.273	0.267	0.259	0.261
Spot	0.074	0.078	0.076	0.071	0.065
forward	0.089	0.094	0.092	0.086	0.081

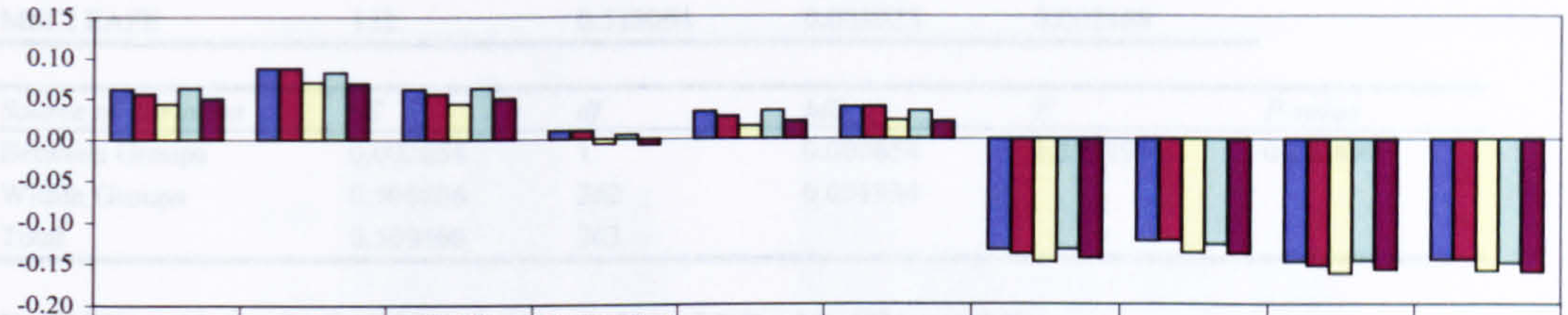
Comparison across 61D SMA, 61D LWMA, 61D EMA, the spot rates and the forward contract



	with trend	with discn	with finance	with div	with currency
117SMA	0.246	0.253	0.248	0.241	0.242
117LWMA	0.240	0.247	0.242	0.235	0.236
117EMA	0.242	0.249	0.244	0.237	0.238
Spot rates	0.074	0.078	0.076	0.071	0.065
Forward	0.089	0.094	0.092	0.086	0.081

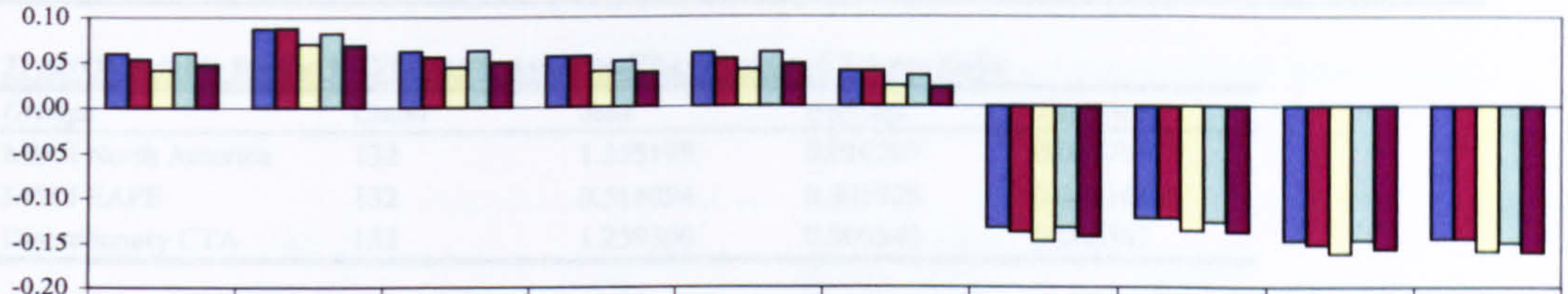
Comparison across 117D SMA, 117D LWMA, 117D EMA, the spot rates and the forward contract

Figure 6.5: Comparison of portfolio compounded returns of 00 and 01 across different currency conversion methods



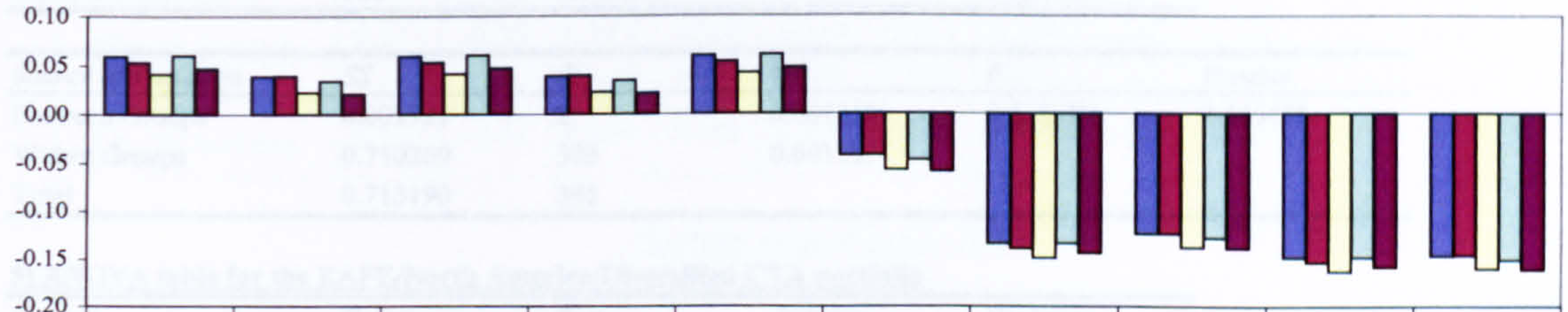
	32SMA_00	32SMA_01	32LWMA_00	32LWMA_01	32EMA_00	32EMA_01	Spot_00	spot_01	Forward_00	forward_01
with trend	0.062	0.087	0.062	0.010	0.033	0.039	-0.134	-0.124	-0.149	-0.147
with discn	0.056	0.088	0.056	0.011	0.027	0.039	-0.139	-0.124	-0.154	-0.147
with finance	0.044	0.070	0.044	-0.006	0.016	0.023	-0.149	-0.138	-0.163	-0.160
with div	0.063	0.082	0.063	0.005	0.034	0.034	-0.134	-0.128	-0.148	-0.151
with currency	0.050	0.069	0.050	-0.007	0.022	0.021	-0.144	-0.139	-0.159	-0.162

Comparison across 32D SMA, 32D EMA, 32D LWMA, the spot rates and the forward contract for 2000 and 2001



	61SMA_00	61SMA_01	61LWMA_00	61LWMA_01	61EMA_00	61EMA_01	Spot_00	spot_01	Forward_00	forward_01
with trend	0.059	0.087	0.062	0.056	0.059	0.039	-0.134	-0.124	-0.149	-0.147
with discn	0.053	0.088	0.056	0.057	0.053	0.039	-0.139	-0.124	-0.154	-0.147
with finance	0.041	0.070	0.044	0.039	0.041	0.023	-0.149	-0.138	-0.163	-0.160
with div	0.060	0.082	0.063	0.051	0.060	0.034	-0.134	-0.128	-0.148	-0.151
with currency	0.047	0.069	0.050	0.038	0.047	0.021	-0.144	-0.139	-0.159	-0.162

Comparison across 61D SMA, 61D EMA, 61D LWMA, the spot rates and the forward contract for 2000 and 2001



	117SMA_00	117SMA_01	117LWMA_00	117LWMA_01	117EMA_00	117EMA_01	Spot_00	spot_01	Forward_00	forward_01
with trend	0.059	0.039	0.059	0.039	0.059	-0.043	-0.134	-0.124	-0.149	-0.147
with discn	0.053	0.039	0.053	0.039	0.053	-0.043	-0.139	-0.124	-0.154	-0.147
with finance	0.041	0.023	0.041	0.023	0.041	-0.058	-0.149	-0.138	-0.163	-0.160
with div	0.060	0.034	0.060	0.034	0.060	-0.048	-0.134	-0.128	-0.148	-0.151
with currency	0.047	0.021	0.047	0.021	0.047	-0.060	-0.144	-0.139	-0.159	-0.162

Comparison across 117D SMA, 117D EMA, 117D LWMA, the spot rates and the forward contract for 2000 and 2001

Appendix 6.1: Statistical output for F Test that test for the variability of the returns (in local currency) among the various groups of assets used within the same portfolio that are used in this chapter

1) ANOVA table for the EAFE/North America portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.002654	1	0.002654	1.372195	0.242499
Within Groups	0.506806	262	0.001934		
Total	0.509460	263			

2) ANOVA table for the EAFE/North America/Trend following CTA portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168
trend following CTA	132	1.098800	0.008324	0.002292

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.002787	2	0.001394	0.678648	0.507896
Within Groups	0.807003	393	0.002053		
Total	0.809791	395			

3) ANOVA table for the EAFE/North America/Discretionary CTA portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168
Discretionary CTA	132	1.259300	0.009540	0.000367

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.003180	2	0.001590	1.126288	0.325279
Within Groups	0.554826	393	0.001412		
Total	0.558006	395			

4) ANOVA table for the EAFE/North America/Finance CTA portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168
Finance CTA	132	1.166300	0.008836	0.001553

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.002921	2	0.001460	0.808029	0.446475
Within Groups	0.710269	393	0.001807		
Total	0.713190	395			

5) ANOVA table for the EAFE/North America/Diversified CTA portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168
Diversified CTA	132	1.013300	0.007677	0.001174

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.002684	2	0.001342	0.798331	0.450808
Within Groups	0.660638	393	0.001681		
Total	0.663322	395			

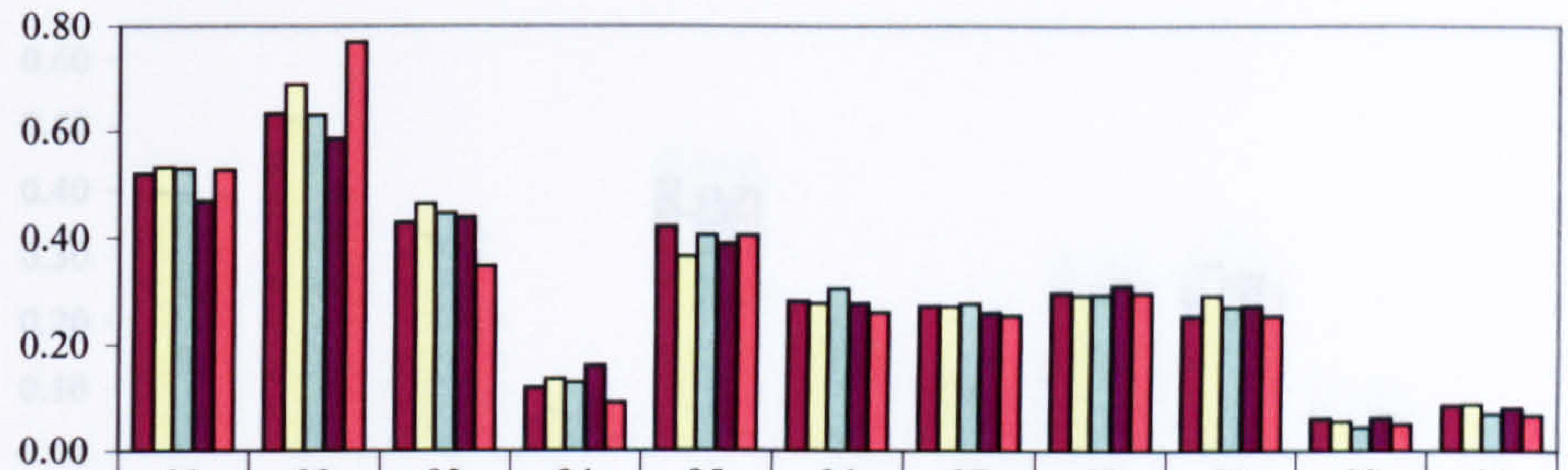
6) ANOVA table for the EAFE/North America/Currency CTA portfolio

Groups	*Count*	*Sum*	*Average*	*Variance*
MSCI North America	132	1.355199	0.010267	0.001701
MSCI EAFE	132	0.518094	0.003925	0.002168
Currency CTA	132	0.884300	0.006699	0.001274

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	0.002668	2	0.001334	0.778184	0.459946
Within Groups	0.673744	393	0.001714		
Total	0.676412	395			

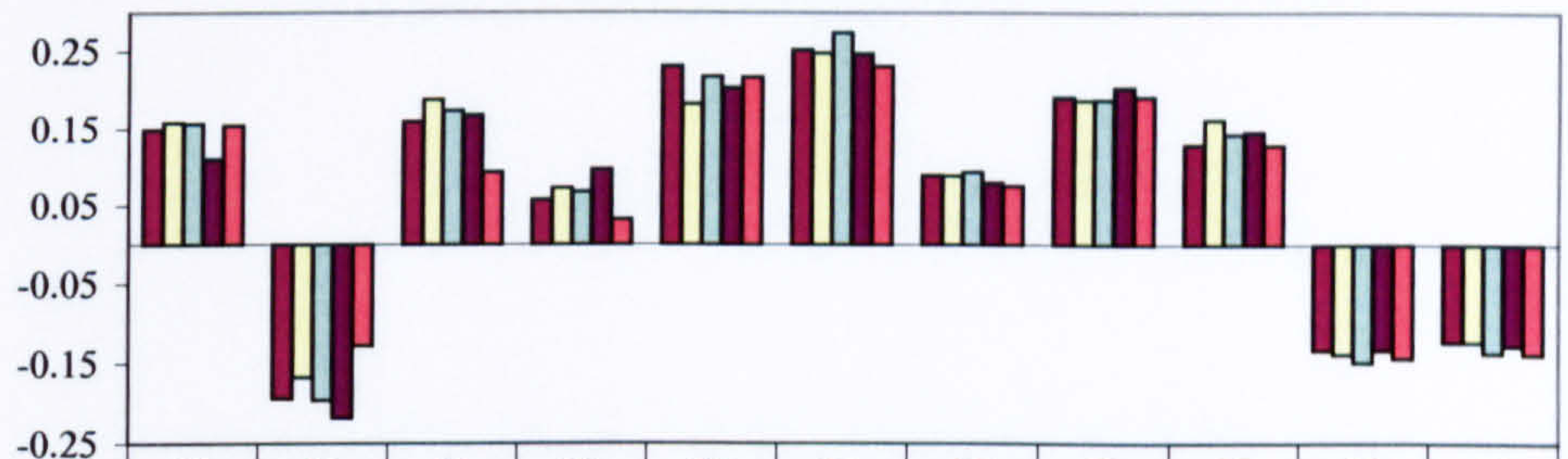
Appendix 6.2A

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 32 days Simple Moving Averages for the Active Currency Mangement approach from 1991 to 2001



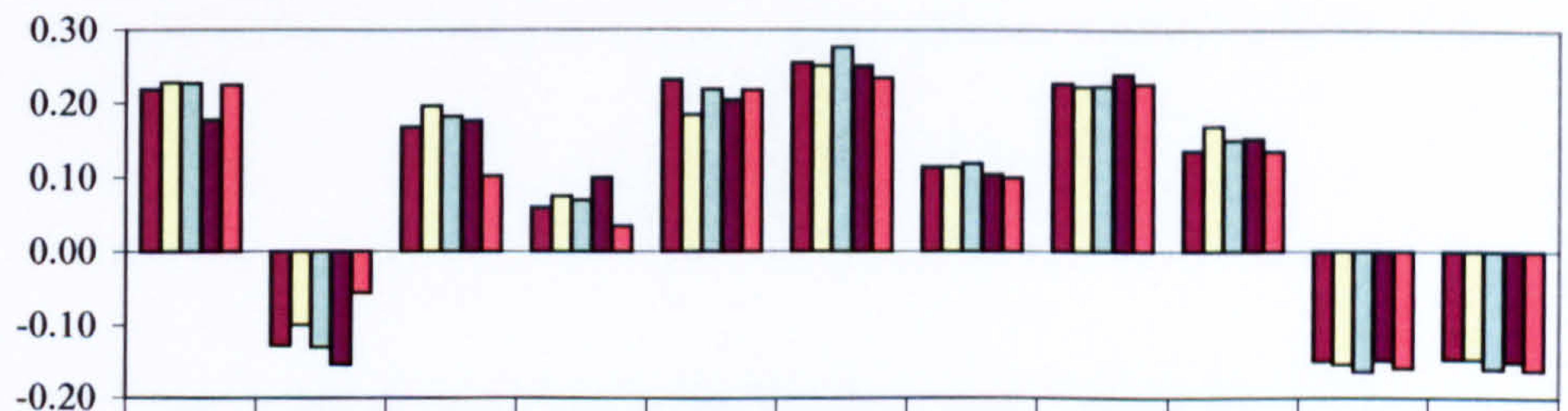
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.520	0.635	0.427	0.119	0.420	0.282	0.272	0.296	0.254	0.062	0.087
with discn	0.532	0.689	0.462	0.135	0.364	0.278	0.272	0.292	0.290	0.056	0.088
with finance	0.530	0.631	0.445	0.129	0.404	0.305	0.277	0.293	0.270	0.044	0.070
with div	0.469	0.587	0.437	0.161	0.388	0.278	0.260	0.310	0.272	0.063	0.082
with currency	0.527	0.770	0.346	0.092	0.403	0.261	0.255	0.296	0.253	0.050	0.069

Portfolio using the 32 days Simple Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot rates



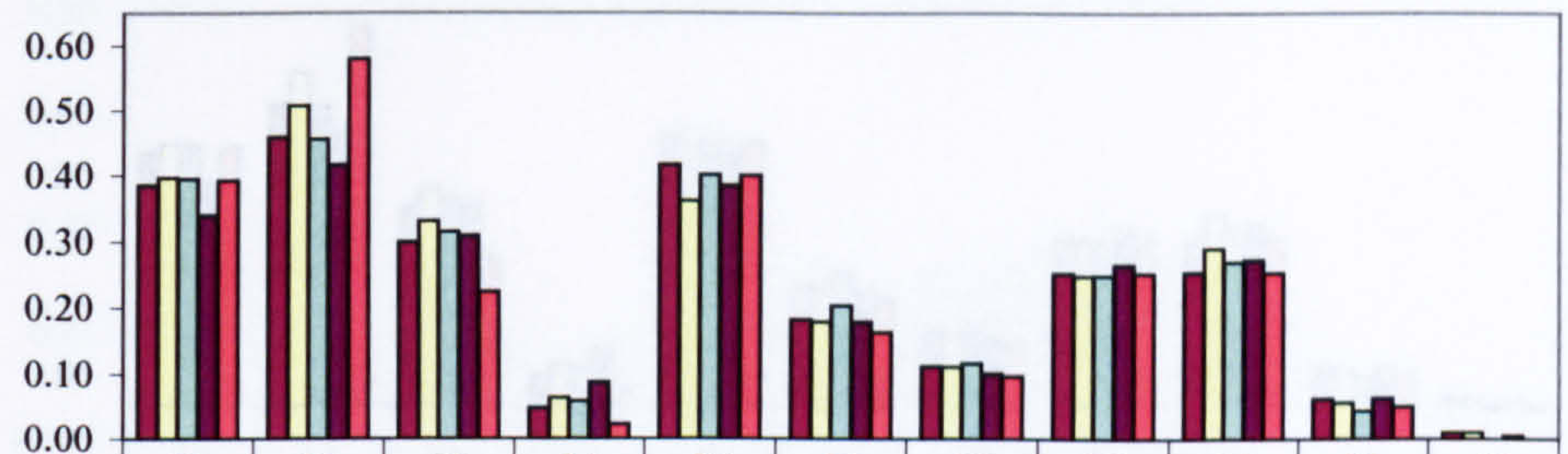
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend | with discn | with finance | with div | with currency

Portfolio using the forwad contracts

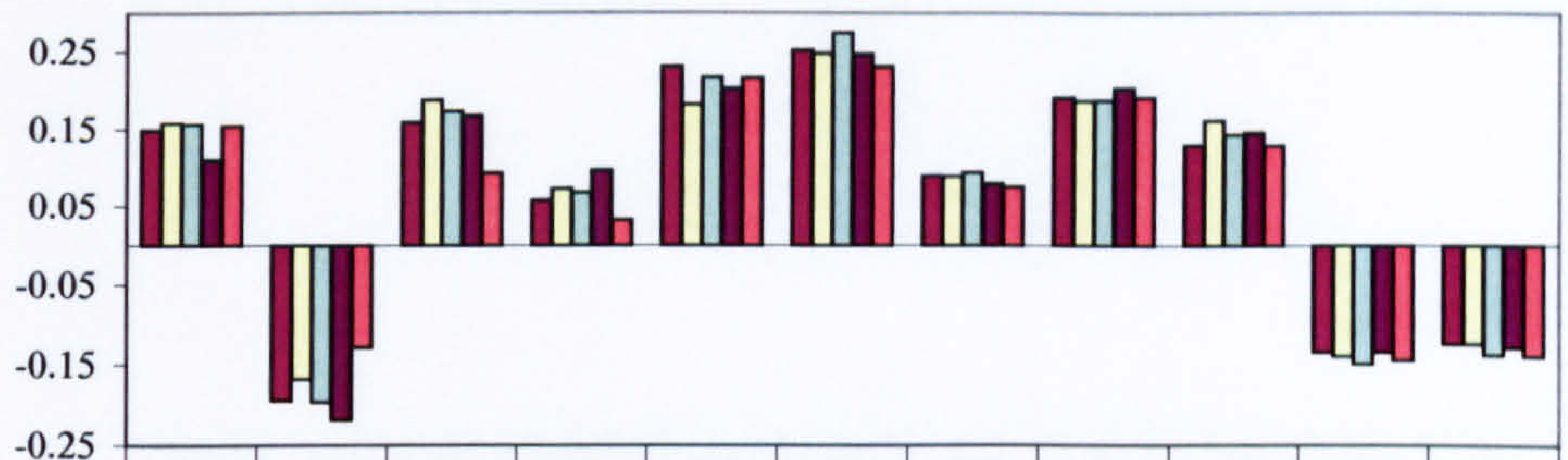
Appendix 6.2B

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 32 days Exponential Moving Averages for the Active Currency Mangement approach from 1991 to 2001



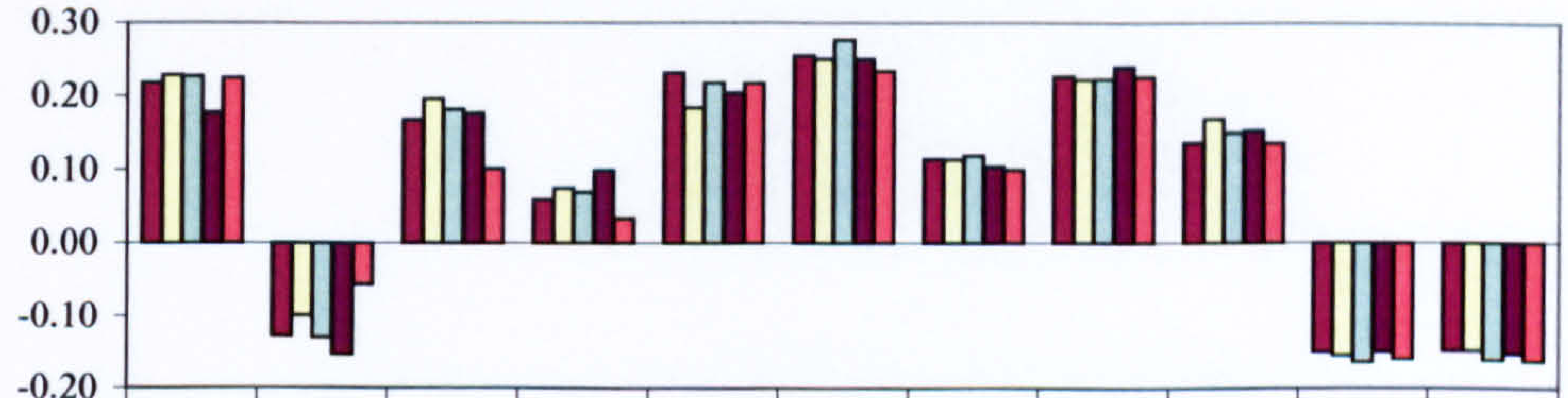
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.386	0.459	0.299	0.048	0.417	0.183	0.111	0.252	0.254	0.062	0.010
with discn	0.397	0.508	0.330	0.063	0.361	0.179	0.111	0.248	0.290	0.056	0.011
with finance	0.396	0.456	0.315	0.058	0.401	0.204	0.116	0.249	0.270	0.044	-0.00
with div	0.340	0.416	0.308	0.087	0.385	0.179	0.101	0.265	0.272	0.063	0.005
with currency	0.393	0.580	0.224	0.023	0.401	0.163	0.096	0.252	0.253	0.050	-0.00

Portfolio using the 32 days Exponential Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot rates



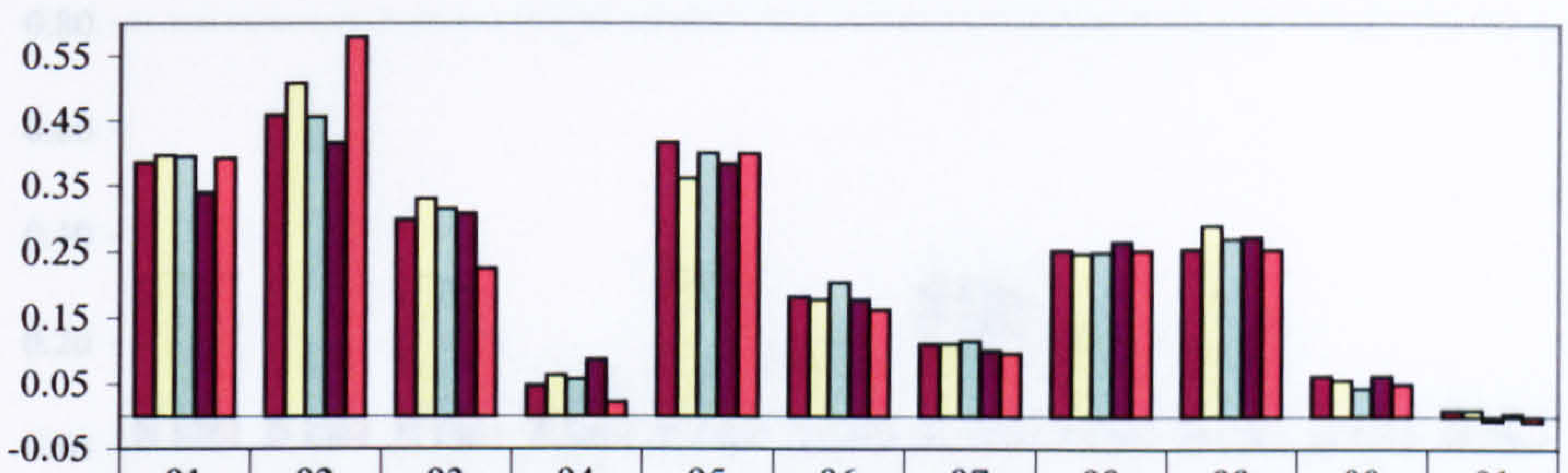
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend · with discn · with finance · with div · with currency

Portfolio using the forward contracts

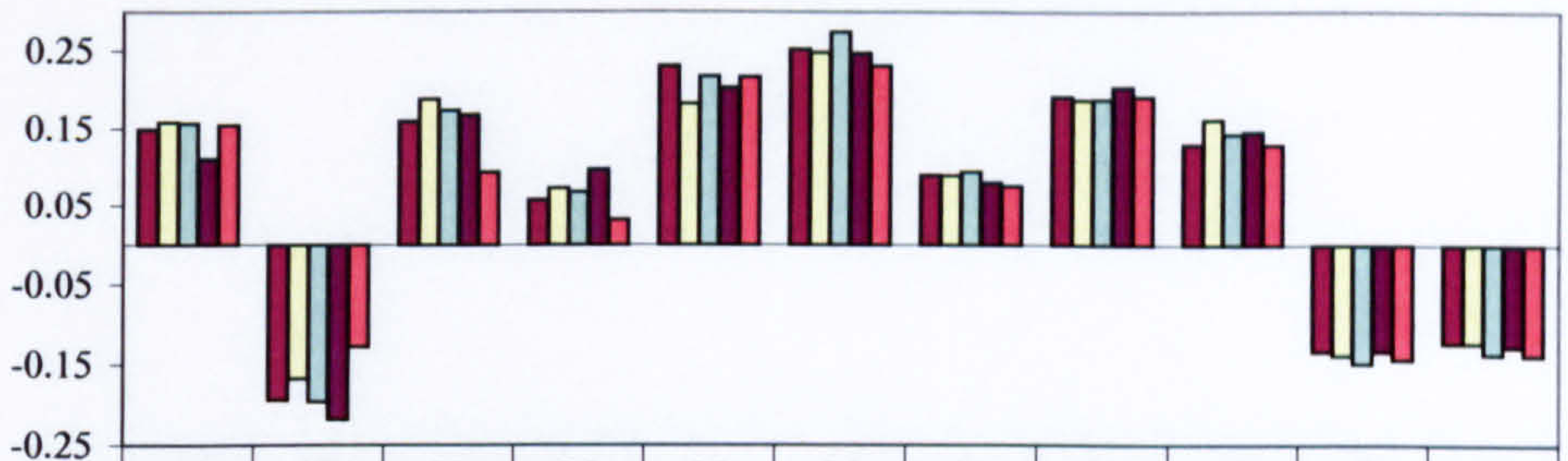
Appendix 6.2C

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 32 days Linearly Weighted Moving Averages for the Active Currency Mangement approach from 1991 to 2001



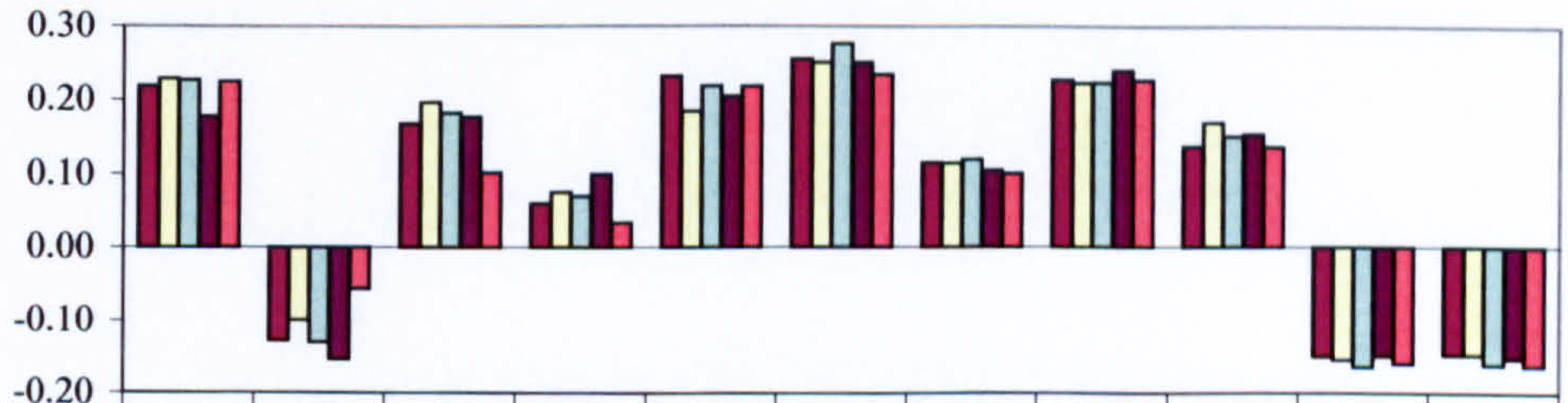
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.386	0.459	0.299	0.048	0.417	0.183	0.111	0.252	0.254	0.062	0.010
with discn	0.397	0.508	0.330	0.063	0.361	0.179	0.111	0.248	0.290	0.056	0.011
with finance	0.396	0.456	0.315	0.058	0.401	0.204	0.116	0.249	0.270	0.044	-0.00
with div	0.340	0.416	0.308	0.087	0.385	0.179	0.101	0.265	0.272	0.063	0.005
with currency	0.393	0.580	0.224	0.023	0.401	0.163	0.096	0.252	0.253	0.050	-0.00

Portfolio using the 32 days Linearly Weighted Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot Rates



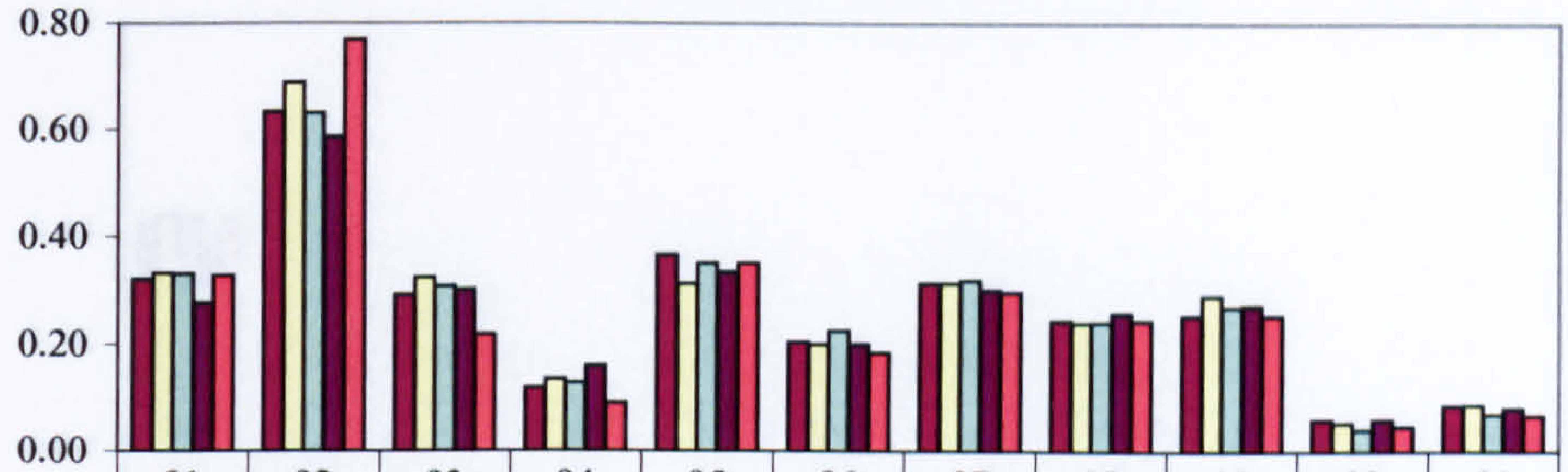
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend | with discn | with finance | with div | with currency

Portfolio using the forward contracts

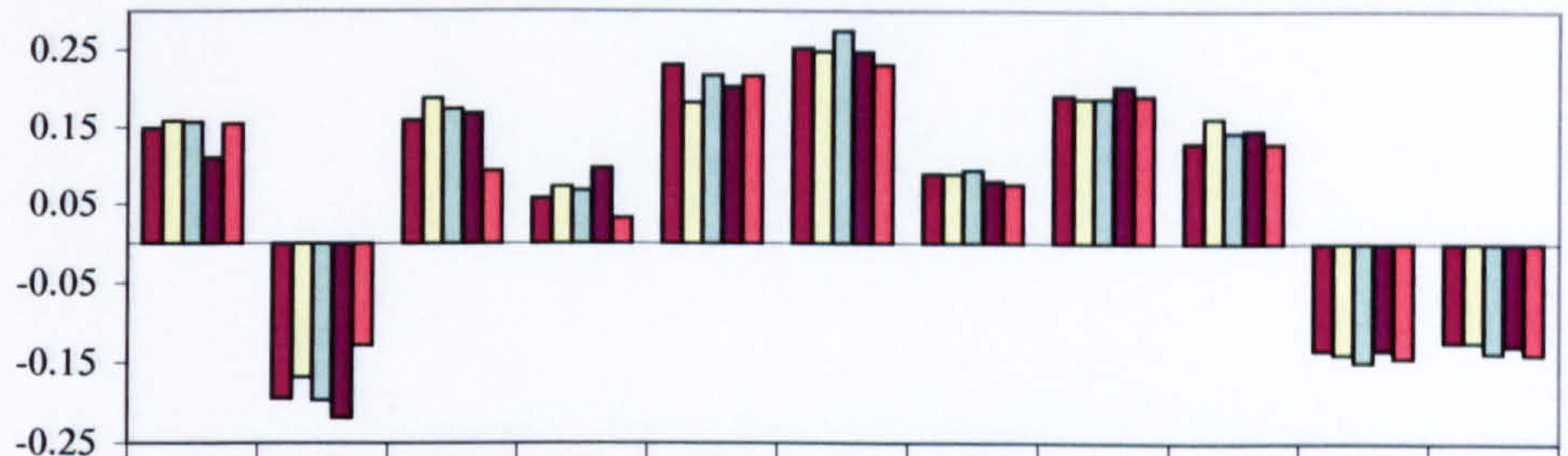
Appendix 6.3A

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 61 days Simple Moving Averages for the Active Currency Mangement approach from 1991 to 2001



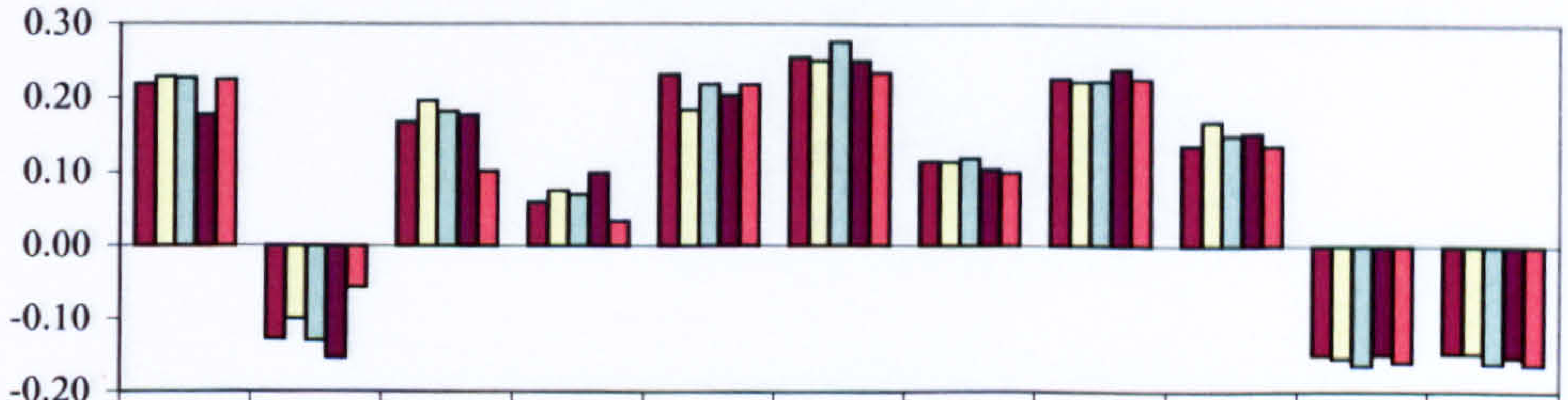
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.322	0.635	0.292	0.119	0.366	0.204	0.314	0.245	0.254	0.059	0.087
with discn	0.332	0.689	0.324	0.135	0.312	0.200	0.313	0.240	0.290	0.053	0.088
with finance	0.331	0.631	0.308	0.129	0.350	0.226	0.319	0.241	0.270	0.041	0.070
with div	0.278	0.587	0.301	0.161	0.335	0.200	0.301	0.257	0.272	0.060	0.082
with currency	0.328	0.770	0.218	0.092	0.350	0.184	0.296	0.244	0.253	0.047	0.069

Portfolio using the 61 days Simple Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot Rates



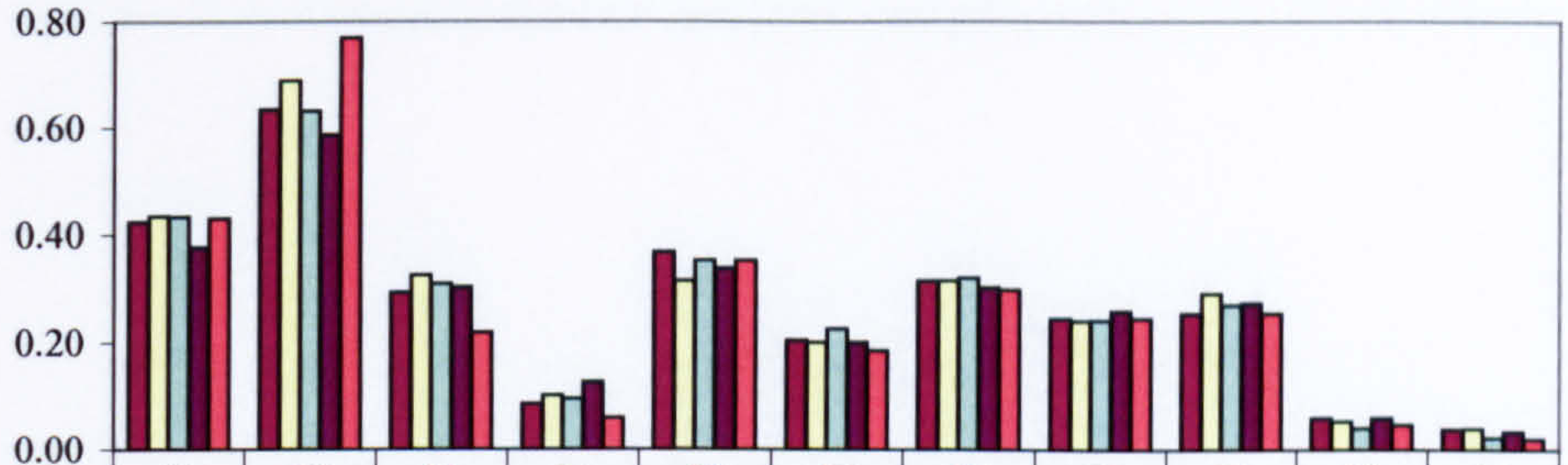
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend / with discn / with finance / with div / with currency

Portfolio using the Forwad contracts

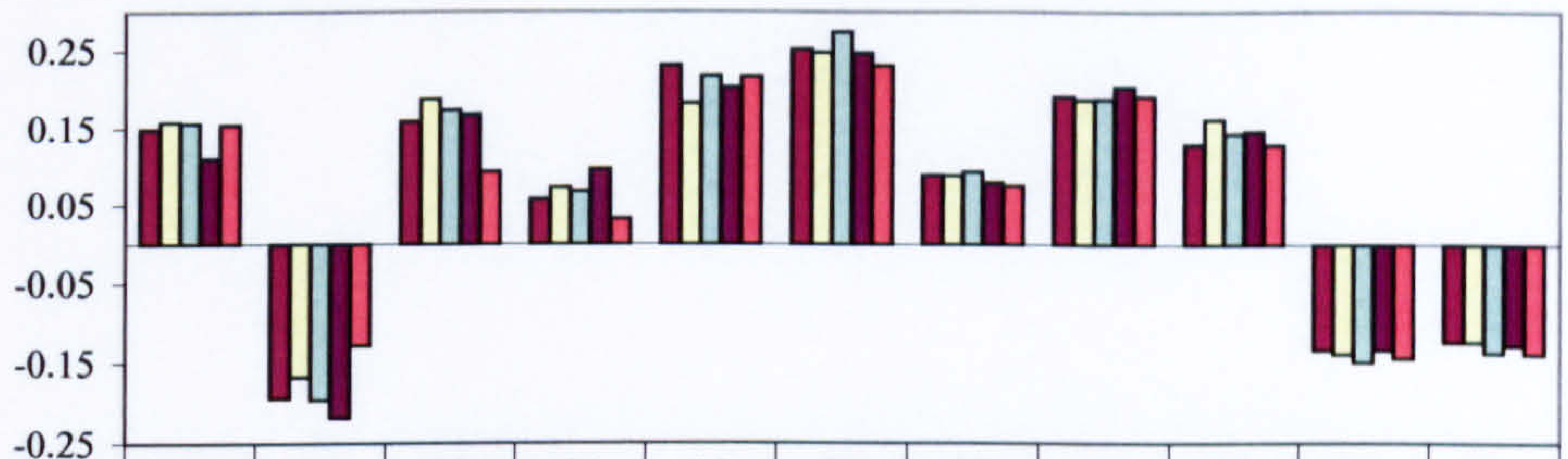
Appendix 6.3B

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 61 days Exponential Moving Averages for the Active Currency Mangement approach from 1991 to 2001



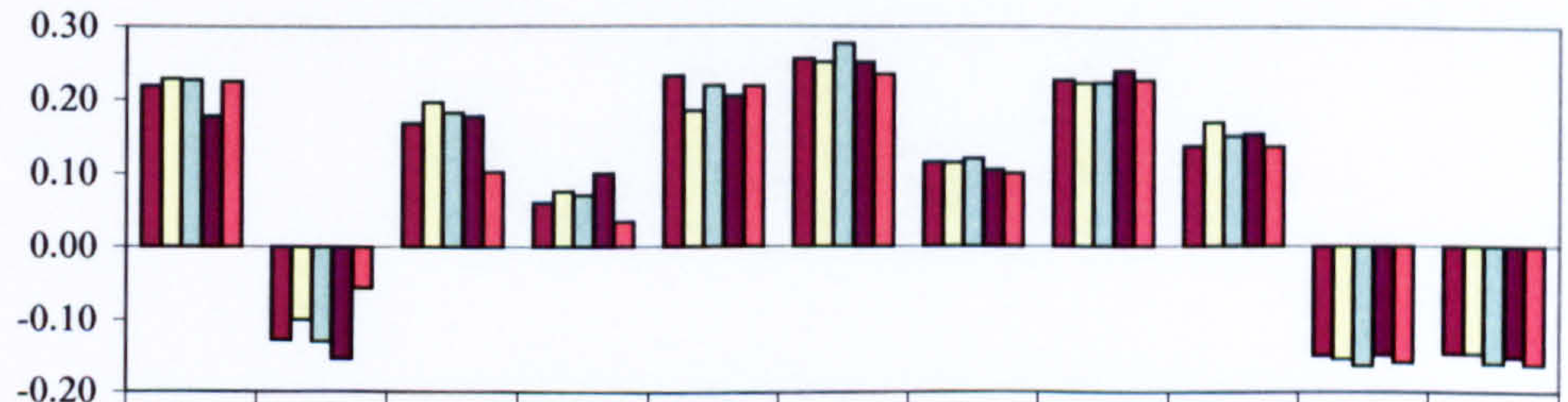
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.423	0.635	0.292	0.086	0.367	0.204	0.314	0.245	0.254	0.059	0.039
with discn	0.435	0.689	0.324	0.101	0.314	0.200	0.313	0.240	0.290	0.053	0.039
with finance	0.433	0.631	0.308	0.096	0.352	0.226	0.319	0.241	0.270	0.041	0.023
with div	0.376	0.587	0.301	0.126	0.336	0.200	0.301	0.257	0.272	0.060	0.034
with currency	0.430	0.770	0.218	0.059	0.351	0.184	0.296	0.244	0.253	0.047	0.021

Portfolio using the 61 days Exponential Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot Rates



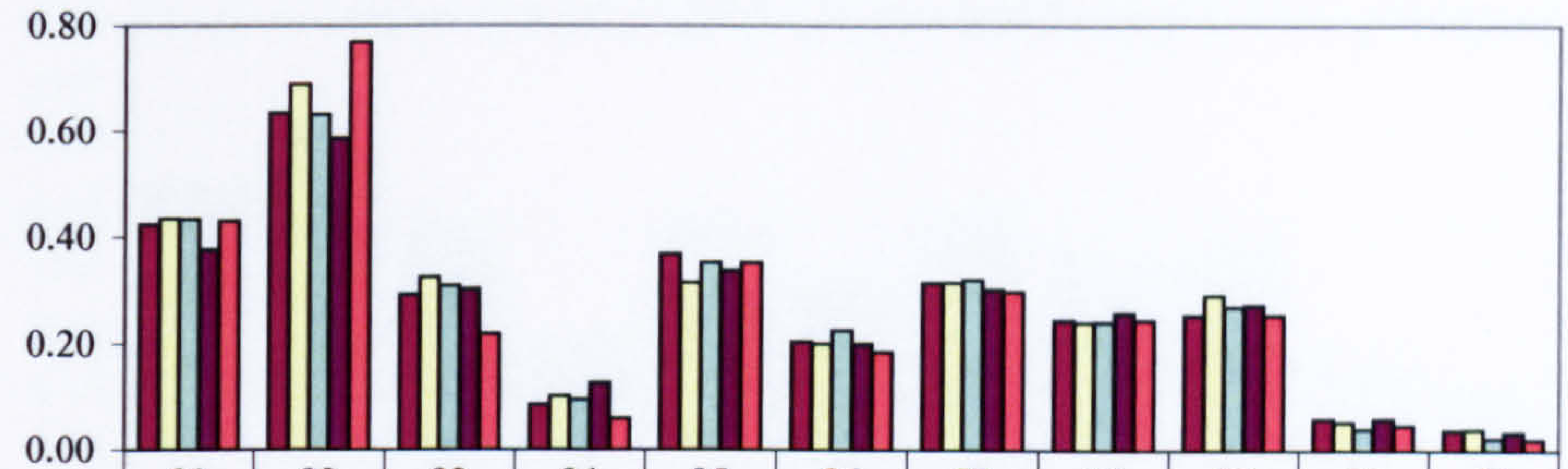
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend □ with discn □ with finance ■ with div □ with currency

Portfolio using the Forwad contracts

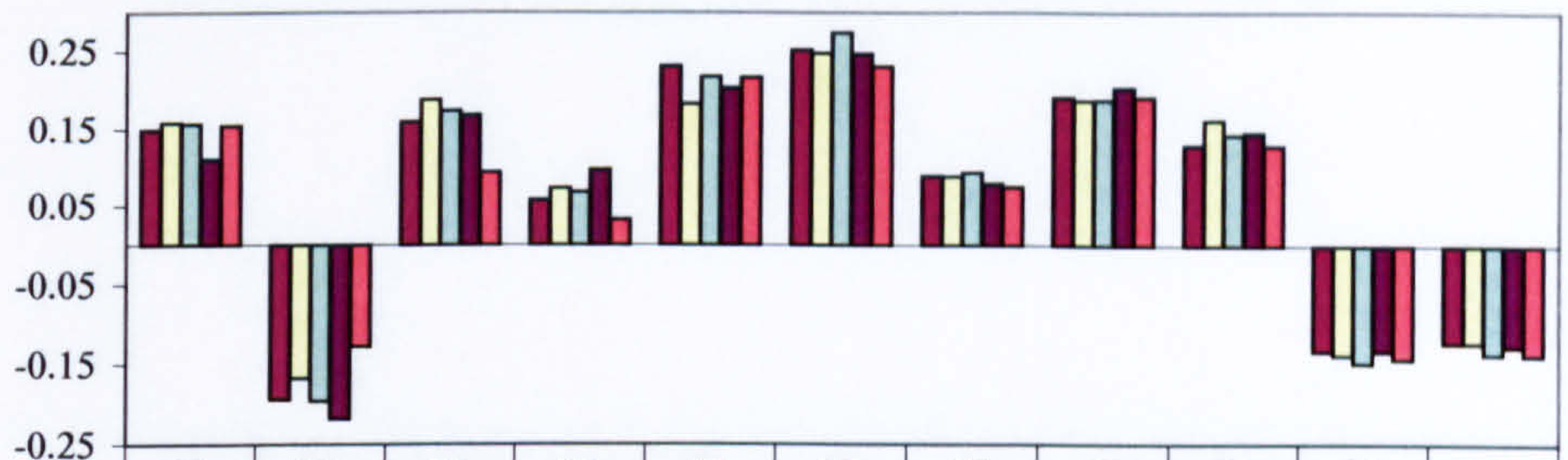
Appendix 6.3C

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 61 days Linearly Weighted Moving Averages for the Active Currency Mangement approach from 1991 to 2001



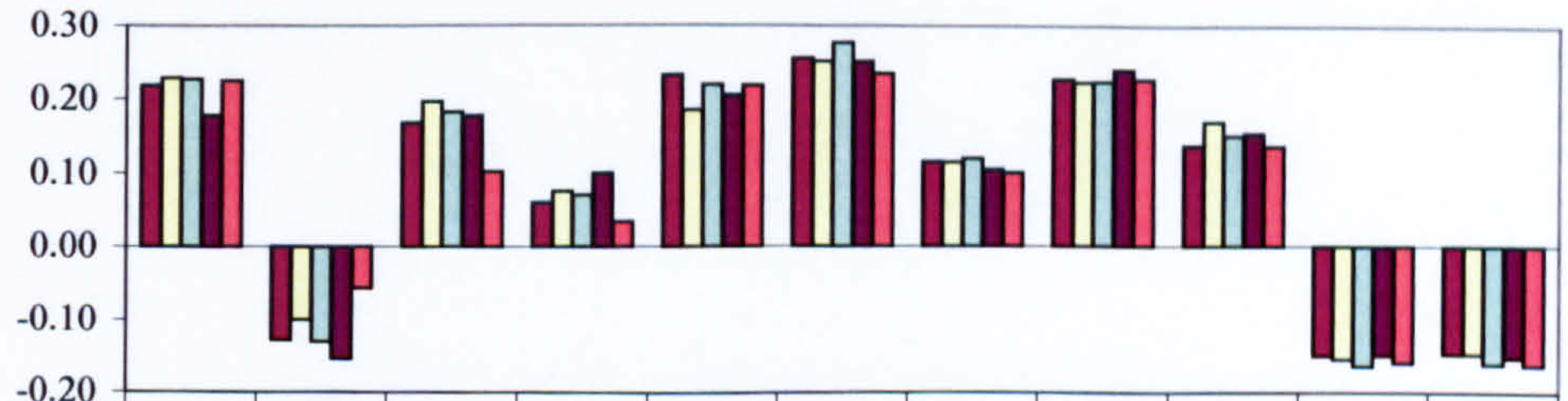
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.423	0.635	0.292	0.086	0.367	0.204	0.314	0.245	0.254	0.059	0.039
with discn	0.435	0.689	0.324	0.101	0.314	0.200	0.313	0.240	0.290	0.053	0.039
with finance	0.433	0.631	0.308	0.096	0.352	0.226	0.319	0.241	0.270	0.041	0.023
with div	0.376	0.587	0.301	0.126	0.336	0.200	0.301	0.257	0.272	0.060	0.034
with currency	0.430	0.770	0.218	0.059	0.351	0.184	0.296	0.244	0.253	0.047	0.021

Portfolio using the 61 days Linearly Weighted Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot Rates



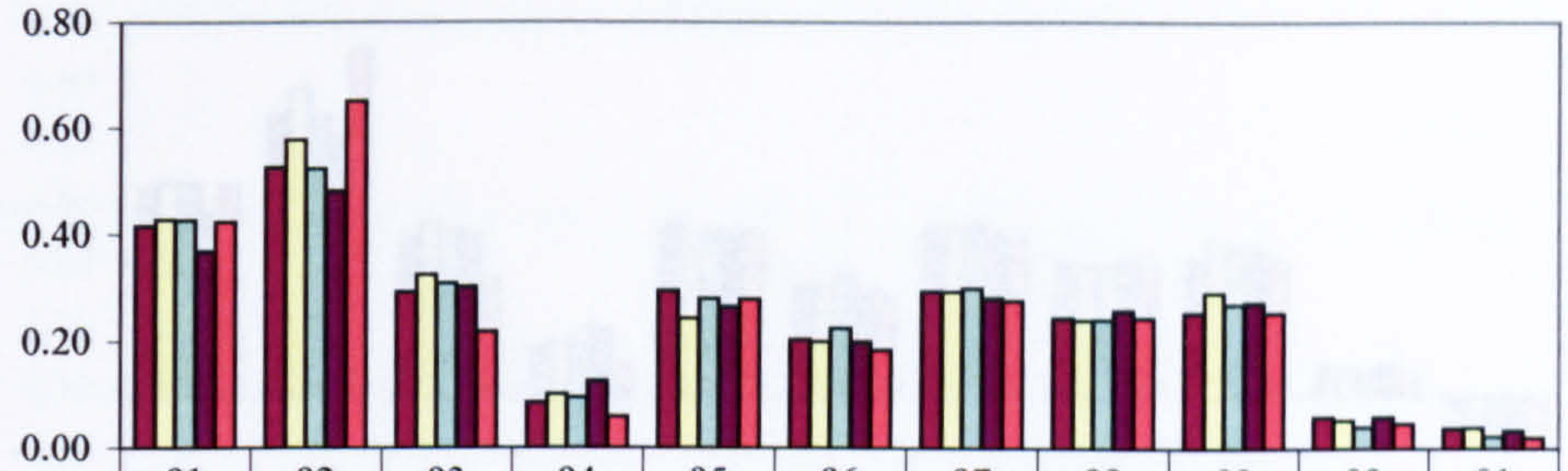
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend | with discn | with finance | with div | with currency

Portfolio using the Forwad contracts

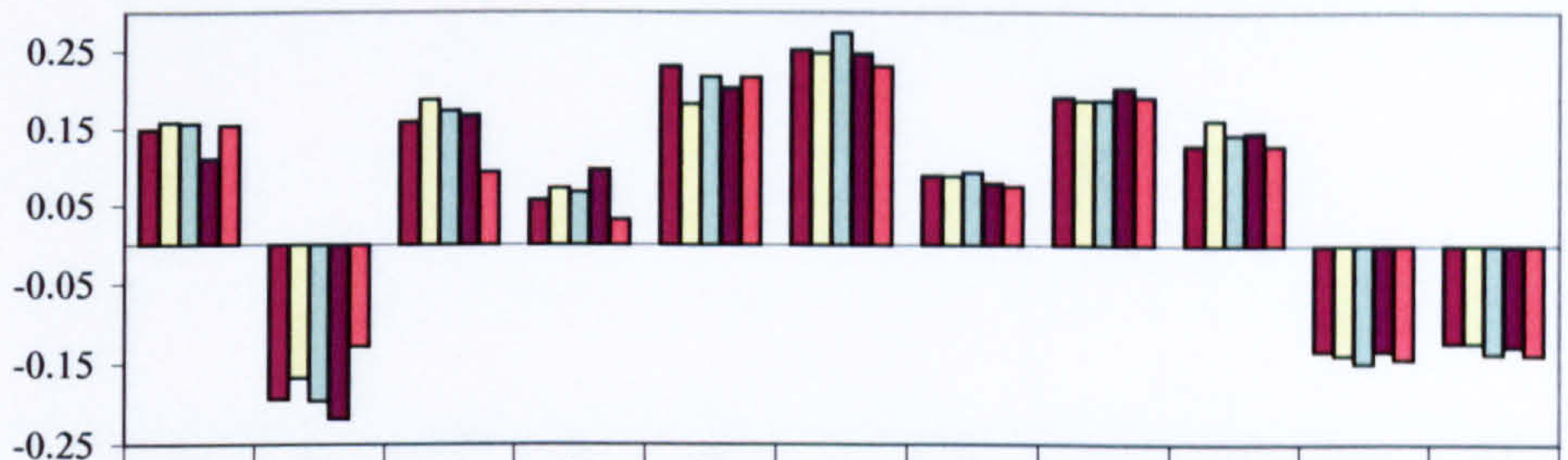
Appendix 6.4A

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 117 days Simple Moving Averages for the Active Currency Mangement approach from 1991 to 2001



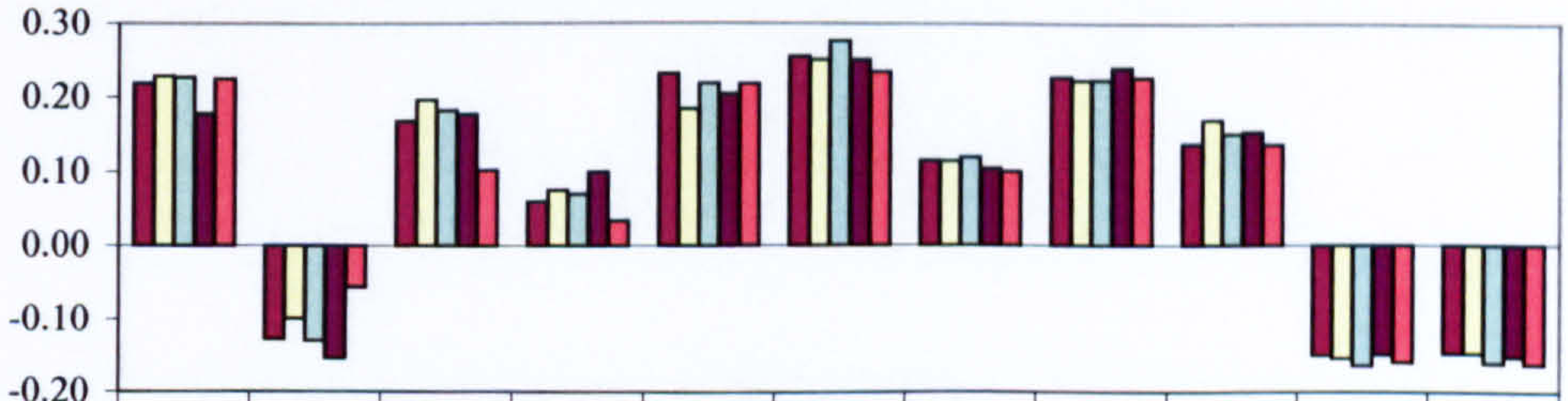
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.416	0.526	0.292	0.086	0.294	0.204	0.293	0.245	0.254	0.059	0.039
with discn	0.427	0.576	0.324	0.101	0.244	0.200	0.293	0.240	0.290	0.053	0.039
with finance	0.425	0.522	0.308	0.096	0.280	0.225	0.298	0.241	0.270	0.041	0.023
with div	0.368	0.481	0.301	0.126	0.265	0.200	0.281	0.257	0.272	0.060	0.034
with currency	0.423	0.651	0.218	0.059	0.279	0.184	0.276	0.244	0.253	0.047	0.021

Portfolio using the 117 days Simple Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot rates



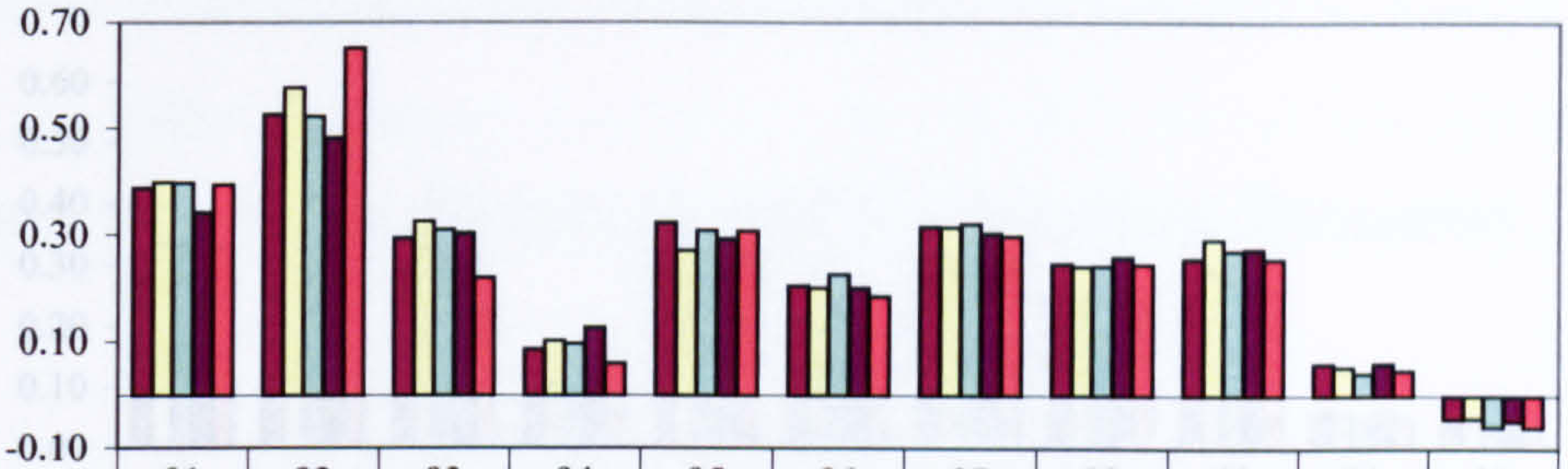
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend · with discn · with finance · with div · with currency

Portfolio using the forward contracts

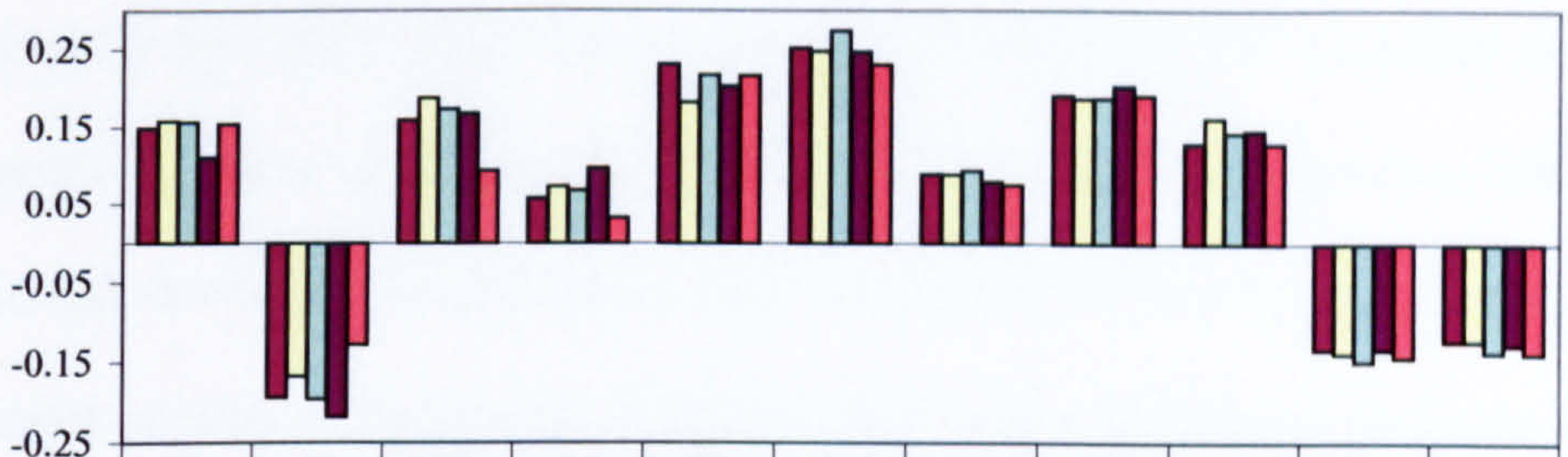
Appendix 6.4B

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 117 days Exponential Moving Averages for the Active Currency Mangement approach from 1991 to 2001



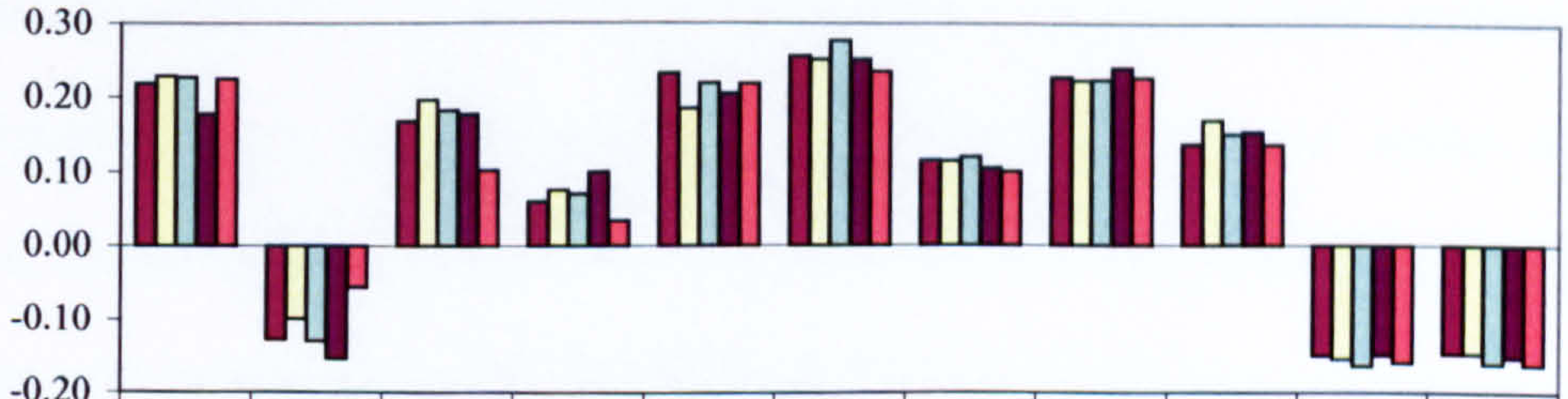
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.386	0.526	0.292	0.086	0.321	0.204	0.314	0.245	0.254	0.059	-0.04
with discn	0.397	0.576	0.324	0.101	0.269	0.200	0.313	0.240	0.290	0.053	-0.04
with finance	0.396	0.522	0.308	0.096	0.306	0.226	0.319	0.241	0.270	0.041	-0.05
with div	0.340	0.481	0.301	0.126	0.291	0.200	0.301	0.257	0.272	0.060	-0.04
with currency	0.393	0.651	0.218	0.059	0.306	0.184	0.296	0.244	0.253	0.047	-0.06

Portfolio using the 117 days Exponential Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot rates



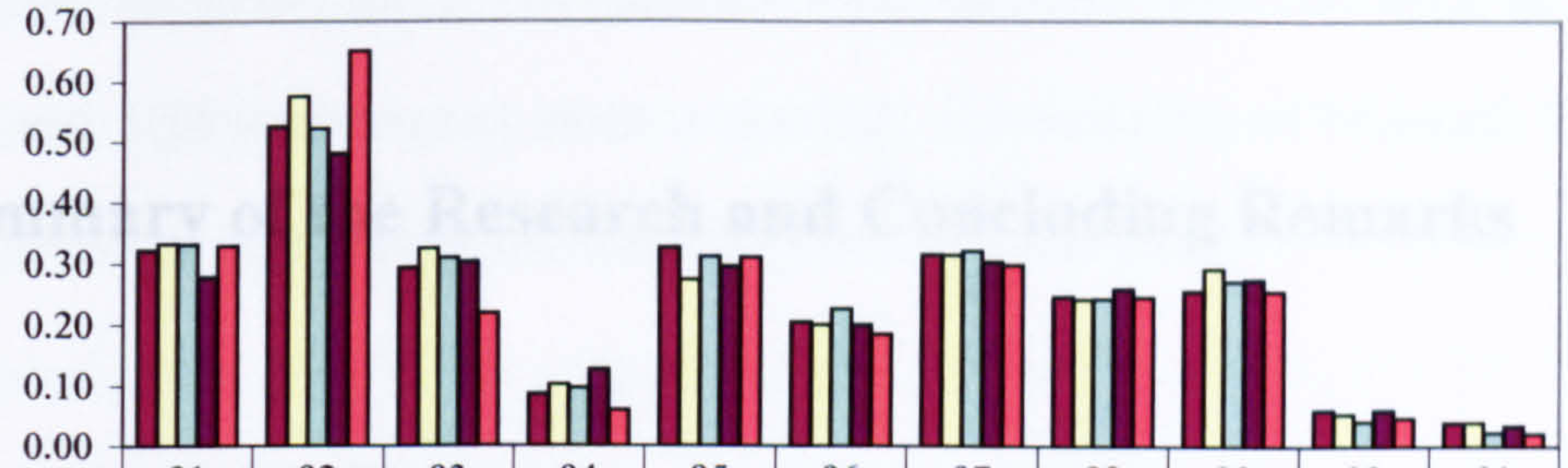
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend   with discn   with finance   with div   with currency

Portfolio using the forward contracts

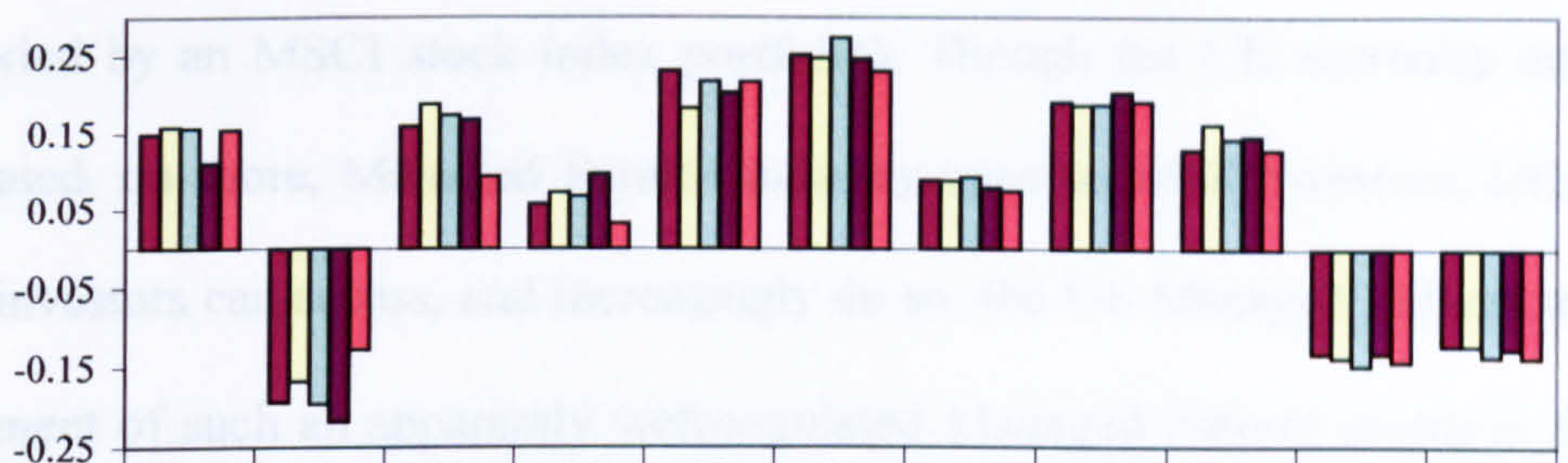
Appendix 6.4C

Comparison of the equally weighted portfolio returns, consisting of MSCI EAFE, MSCI North America and the Managed Futures indexes, using spot rates, forward contracts and the 117 days Linearly Weighted Moving Averages for the Active Currency Mangement approach from 1991 to 2001



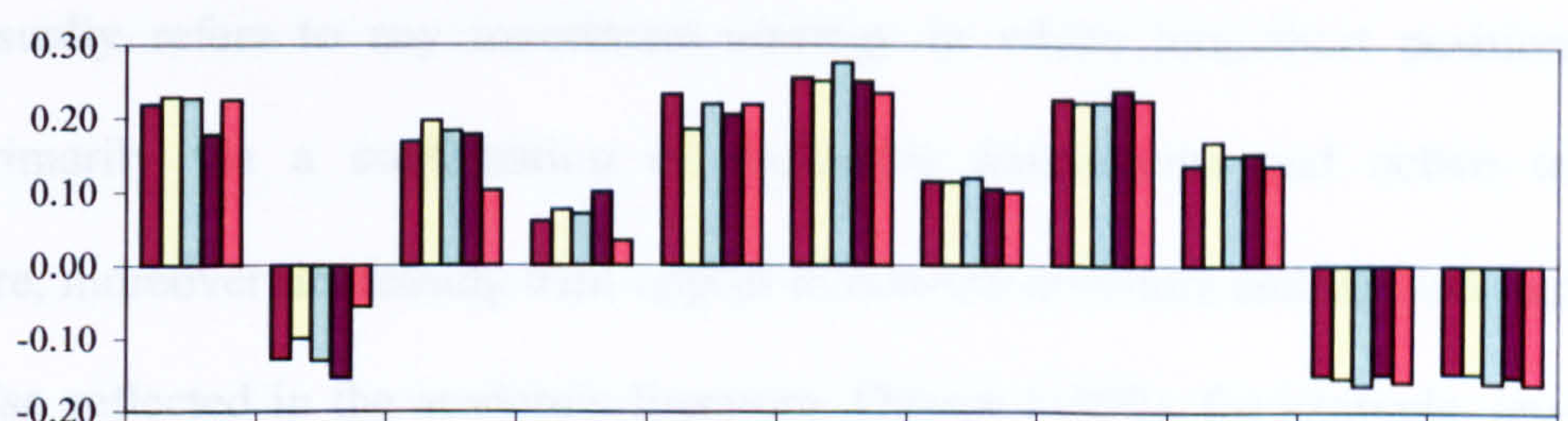
	91	92	93	94	95	96	97	98	99	00	01
with trend	0.322	0.526	0.292	0.086	0.325	0.204	0.314	0.245	0.254	0.059	0.039
with discn	0.332	0.576	0.324	0.101	0.273	0.200	0.313	0.240	0.290	0.053	0.039
with finance	0.331	0.522	0.308	0.096	0.310	0.226	0.319	0.241	0.270	0.041	0.023
with div	0.278	0.481	0.301	0.126	0.295	0.200	0.301	0.257	0.272	0.060	0.034
with currency	0.328	0.651	0.218	0.059	0.309	0.184	0.296	0.244	0.253	0.047	0.021

Portfolio using the 117 days Linearly Weighted Moving Averages for Active Currency Management



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.149	-0.19	0.160	0.058	0.231	0.252	0.090	0.192	0.130	-0.13	-0.12
with discn	0.158	-0.16	0.188	0.073	0.183	0.248	0.090	0.187	0.163	-0.13	-0.12
with finance	0.157	-0.19	0.174	0.068	0.217	0.274	0.095	0.189	0.144	-0.14	-0.13
with div	0.111	-0.21	0.168	0.097	0.203	0.248	0.080	0.204	0.147	-0.13	-0.12
with currency	0.155	-0.12	0.094	0.032	0.217	0.231	0.076	0.191	0.130	-0.14	-0.13

Portfolio using the spot rates



	91	92	93	94	95	96	97	98	99	00	01
with trend	0.218	-0.128	0.168	0.060	0.232	0.254	0.114	0.226	0.135	-0.149	-0.147
with discn	0.228	-0.099	0.196	0.075	0.183	0.250	0.113	0.221	0.168	-0.154	-0.147
with finance	0.227	-0.130	0.182	0.069	0.218	0.276	0.118	0.222	0.149	-0.163	-0.160
with div	0.178	-0.154	0.176	0.099	0.204	0.250	0.103	0.238	0.152	-0.148	-0.151
with currency	0.224	-0.056	0.101	0.034	0.217	0.233	0.099	0.226	0.135	-0.159	-0.162

with trend | with discn | with finance | with div | with currency

Portfolio using the Forward contracts

Chapter 7

Summary of the Research and Concluding Remarks

7.0 Introduction to the Chapter

This Thesis has examined the development and performance of the Managed Futures industry. More specifically, the research has focused on the performance, potential uses and portfolio risk-return benefits to UK investors of Managed Futures within a portfolio context (proxied by an MSCI stock index portfolio). Though the UK currently does not have a regulated, on-shore, Managed Futures industry open to retail investors, UK-based institutional investors can access, and increasingly do so, the US Managed Futures market. The development of such an apparently well-regulated Managed Futures sector in the US both suggests a plausible model for future UK developments in this area, whilst also providing an indication of the possible foregone benefits suffered by UK retail investors from not having the same opportunities as US investors to access Managed Futures investments. Managed Futures and other alternative investments such as hedge funds (a term that usually refers to any investment strategy in which long-short positions are achieved primarily via a combination of derivative instruments and active trading strategies) are, moreover, increasing their appeal to non-US investors and this international interest is also reflected in the academic literature. Oberuc (1992), for example, analyzed the effect of using Managed Futures in combination with non-US (4 European) investment portfolios over the period 1979 to 1989. Evidence from the practitioner community also shows a similar increased interest in this area. One UK based Managed Futures firm, RXR

Capital investment (Allen, 1999), to our knowledge, has reported to have found that, using data from 1989 to 1998, for a UK pension fund portfolio that consisted of UK£-denominated and US$-denominated stock and bonds, the inclusion of Managed Futures significantly improved portfolio returns expressed in UK£ (unhedged).

The increased recognition of Managed Futures as a distinct asset class is largely due to the size and liquidity of the futures markets, which in the US have matured to the point where managed funds can now claim to provide investors with genuine alternative investment opportunities. The substantial growth of investment funds being committed to specialized futures fund management is clearly strong evidence consistent with the claims made by alternative investment traders. As mentioned above, the expansion of this market in the US has also begun to attract significant cross-border (i.e., non-US) investor interest. Demand from within the EU, would no doubt be greatly increased if these countries followed the US and allowed retail investors access to regulated Managed Futures investments. As it is, retail, high net worth and institutional investors in the EU all typically have to use an unregulated agent, often domiciled in an off-shore tax haven, if they wish to access Managed Futures investments. Adopting the US regulatory approach would make access to the US markets considerably easier and would also be expected to stimulate the development of the new EU-based instruments and markets.

The Research of this Thesis on assessing the viability of using Managed Futures as part of an internationally diversified UK portfolio is also supported by the empirical findings regarding the effectiveness of using Managed Futures, as compared to hedge funds, as potential portfolio diversifiers found in Edwards and Caglayan (2001) and Kat (2002).

In order to estimate the potential incremental benefits to UK investors associated with access to US dollar based Managed Futures products, the research had to determine a method of simulating and analyzing these incremental benefits in terms of UK investor realized portfolio risks and returns. To date, there has not been much published research on this topic and therefore despite the exploratory nature of this investigation, the findings presented in this Thesis have a greater potential to make a contribution to the existing literature on the use and effectiveness of Managed Futures within a UK investor portfolio. As discussed in the introductory chapter, in this thesis three different approaches have been adopted to ascertain the benefits of using US dollar based off shore Managed Futures within a UK portfolio. Basically, we examined the portfolio allocation benefits to UK investors associated with using US dollar based Managed Futures, using the following allocation mechanisms:

1) within a downside risk framework (Chapter 4),
2) using a conditional volatility based Optimization framework (Chapter 5) and,
3) within an active currency management framework (Chapter 6)

7.1 Summary of the Research, Main Findings and Contributions of the Thesis

7.1.1 Summary of the Research, Main Findings and Contributions of Chapter 4

This first Empirical Research Chapter examined the issue of asset allocation from the perspective of the distributional characteristics of the returns of the assets underlying the portfolio. Managed Futures are relevant because there was empirical evidence which suggesteds that the distributional characteristics of Managed Futures returns exhibit positive skewness. There are also controversies regarding the suitability and feasibility of using Minimum Variance approaches for assets that exhibit non-normal return distributions. The asset allocation criteria for portfolios that use Managed Futures therefore become an issue when combined with the use of the Minimum Variance approach for asset allocation decisions.

Chapter 4 begins by providing a review of the literature stemming from Markowitz's (1959) original concerns regarding the difficulties of incorporating below target variance and why, despite its limitations, Markowitz eventually opted to focus on variance as the primary risk measure for portfolio selection.

The literature review then focused on the issue of below target variance (or downside risk) and the subsequent development into the Lower Partial Moment framework. What ought to be noted however is that, skewness, which is an important issue underlying the "below target return variance" approach, can also be addressed by simply considering "variance" as a risk measure. The Minimum Variance approach used for portfolio selection utilised the 3 moments (i.e., mean, variance and skewness) of the return distribution and therefore an analysis using only the variance as the risk measure was not undertaken in this chapter.

Analyzing risk as below-target-variance involves focusing on only the return distribution that lies below the target variance. Incorporating this type of risk analysis into the Lower Partial Moment algorithm framework, allows the below-target-variance of the underlying assets to be adjusted and this affects the portfolio skewness.

Nawrocki (1999) explained that incorporating skewness within a portfolio is similar to the idea of purchasing put options, synthetic puts or other forms of portfolio insurance. And this comes with a cost in terms of premium. Likewise, skewness, in this case positive skewness, though essential for reducing downside losses, also comes with a cost. As explained in Nawrocki (1999), this "cost" is incurred in the form of "reduced portfolio returns".

Using the Lower Partial Moment, the main aim of the Chapter was to show that different levels of skewness do have an appreciable impact on portfolio returns. Using the Lower Partial Moment framework, skewness was adjusted in a way that minimized the negative impact of excessive skewness upon portfolio returns. The asset allocation mechanism for portfolios that used the five Managed Futures instruments (i.e., Trend-Following CTA, Discretionary CTA, Diversified CTA, Currency CTA, and Financial CTA) and the seven MSCI Stock Indexes (i.e., MSCI Stock Index for USA, Japan, West Germany, France, Switzerland, Canada and the UK) for 4 years (1990 to 1993) provided evidence of benefits to investors. The results indicated that adjustments for skewness within a portfolio improved the 5 year monthly compounded out sample holding period returns from about 79% to 89%. The highest returns occurred when the portfolio was adjusted for the least skewness, while the lowest returns occurred when the portfolio incorporated the highest level of skewness. This indicated that skewness does affect portfolio returns. When compared to using the Minimum Variance approach for asset allocation over the same time periods and with the same underlying assets, the Minimum Variance approach only managed to produce an out sample holding period return of about 77%. This shows that the choice of asset allocation model is important and this choice can be expected therefore to affect portfolio returns when the underlying assets' exhibit significant skewness. As our findings showed, it has helped improve the out-sample 5 year monthly compounded returns, in the range of 2% to 12%.

7.1.2 Summary of the Research, Main Findings and Contributions of Chapter 5

Chapter 5 continued the investigation into the potential benefits of using Managed Futures within an UK portfolio, by re-assessing the role of Managed Futures. The analysis differs from Chapter 4, which considered the distribution pattern of Managed Futures returns, since in this Chapter the time series of variance was a central issue for the asset allocation process under consideration.

Events such as the October 1987 market crash drew attention to the possibility that the scope of market interactions might include substantial, and hence policy-relevant, second moment linkages. Momentous events such as the 1987 crash has motivated research into the patterns and relative importance of second order linkages between international stock markets. Some examples of previous studies in this area are Hamao et al. (1990), Theodossiou and Lee (1993) and Ng et al. (1991).

The Chapter investigated the extent to which Managed Futures could cushion portfolio volatility during volatile market periods. The time period covered by the data, i.e., from 1980 to 2001, is particularly appropriate for an investigation into the performance of portfolios that use Managed Futures. This is because the end of the 1990's and the beginning of the 21st century, was a period that witnessed some of the most volatility-inducing events that have ever occurred in financial history. For example, the Asian currency crisis (1997), the Russian Bond default and Long Term Capital Management collapse (1998), the bursting of the internet and technology stock price bubble (2000) and the September 11th (2001) events.

Considering time varying variance within a portfolio allocation process is to consider variance as a function of its lagged variables. In this case, we consider time varying variance in a functional form that assumes correlation is constant (Constant correlation GARCH).

Two portfolios are considered for Research here. One of which was the MSCI EAFE/Managed future Indexes and the other was the MSCI EAFE/MSCI US Indexes portfolio. It was found that the correlation of returns between the Managed Futures and the EAFE Indexes appeared to be much more lowly correlated. However, those between the North America and the EAFE Indexes appeared to be more significantly (and highly) correlated.

The results also show that correlation of returns between the Managed Futures and the EAFE Indexes about 0.07. The correlation between the North America and the EAFE Indexes, however, is about 0.57. The lower correlation between the Managed Futures and EAFE Indexes then contribute to a lower conditional covariance, when compared to the portfolio of MSCI EAFE index and MSCI US index portfolio.

By using MSCI EAFE and the Managed Futures indexes portfolio, compared to that of the MSCI EAFE and the MSCI US Indexes portfolio, the UK investor gains an incremental benefit of 13.02% for 2000 and 9.75% for 2001. The portfolio volatility (taking into account both 2000 and 2001), however, reduced by 3.07%, and the minimum monthly return improved by 7.66%. This shows that a much lower conditional covariance arising from using Managed Futures within the UK portfolio do appear to have had an impact on curbing portfolio volatility.

7.1.3 Summary of the Research, Main Findings and Contributions of Chapter 6

This Chapter assessed the potential benefit to UK investors of using an Active Currency Management strategy for converting their portfolio returns into UK£ denominated returns. The main focus was on the incremental benefits of adopting Active Currency Management, as compared to using purely forward contracts or spot rates, for converting UK equity portfolio that used Managed Futures.

The Chapter used a moving average trading rule previously used in Acar and Lequeux (2001), Dunis and Levy (2002) and Reinert (2000). These authors simulated a system that generates a signal based upon currency trends, such that it allows one to decide whether to choose the spot rate or forward contracts when converting the foreign currency into the home currency. Single Moving Averages of 32, 61 and 117 days were used to trace the pattern of currency movements, which then generate the signals to decide whether to use the spot rate or the forward contract, when converting the portfolio return into UK pounds. Moving Averages of 32, 61 and 117 days used in previous studies have proved to be effective when applied within an Active Currency Management context. For example, Acar & Lequeux (2001) use 32, 61 and 117 moving average days to construct a currency benchmarking that is built upon Active Currency Management.

To construct the portfolio, the MSCI US index and the MSCI EAFE index were used in conjunctions with each of the following 5 Managed Futures Indexes to form five separate different portfolios: 1) the Trend Following CTA index, 2) the Discretionary CTA index, 3) the Finance CTA index, 4) the Diversified CTA index and 5) the Currency CTA index. Then, the spot rate, forward contract and the Active Currency Management were applied when converting the returns into UK£. The annually compounded returns are then computed for the portfolio and then compared among them.

The Empirical Analysis, based upon data from 1991 to 2001, compared the performance of equity portfolios using Managed Futures on the basis of the three currency conversion methods. Equity portfolios that use Active Currency Management performed far better than those that used either solely spot rates or forward contacts. By considering the performance of the years 2000 and 2001, a period in which the financial markets were particularly volatile, using the spot rate and the forward contract produced negative incremental returns for equity portfolios using Managed Futures. However, most equity portfolios that used Managed Futures produced positive returns in 2000 and 2001, when adopting Active Currency Management. These results provided evidence confirming the effectiveness of applying Active Currency Management on equity portfolio that includes Managed Futures.

The results therefore suggest that there are potentially large benefits to UK institutional investors in being able to access the skills and trading programs currently being offered by off-shore Managed Futures specialists that exploit the inefficiencies and trend opportunities of the highly liquid foreign exchange markets.

7.2 Possible Future Research

The Empirical Research undertaken in this Thesis on the performance and possible uses of Managed Futures within UK portfolios began in Chapter 4 with the presentation of empirical evidence on the effect of distributional patterns of returns on the asset allocation mechanism. In Chapter 4, the plausibility of including the higher moments of the return distribution in the allocation process was explored. Given the non-normality of return distributions and plausible investor risk preferences that focus primarily on avoiding losses, we analyzed the asset allocation decision in terms of the relative effectiveness of the Minimum Variance and Lower Partial Moment approaches. In Chapter 5, time-varying variances were considered in the allocation process and how the inclusion of Managed Futures might help reduce portfolio volatility. Chapter 6 was mainly concerned with simulating technical trading systems and currency hedging decisions since the focus of the analysis was the UK investor. Chapter 6 does not; therefore consider optimization mechanisms regarding the most beneficial asset allocation within the portfolio. Given the relative lack of previous research into Managed Futures, from a UK perspective, its performance undertaken in these Chapters could of course be greatly extended and improved by further research. The following sections will therefore discuss potential areas for future research in relation to the issues addressed by each of the three Empirical Chapters.

7.3 Potential Areas for Future Research

7.3.1 Future Research in respect of the Analyses Addressed by Chapter 4

7.3.1.1 Issues Relating to the Stability of Portfolio Returns

The allocation mechanisms that were used in this and the following Chapter (Chapter 5) were based upon optimization algorithms. It is worth recalling what optimization involves since this also highlights its primary drawback. Optimization involves first determining the most advantageous weighting for the assets in the portfolio on the basis of the in-sample data-set. These weights are then applied to the out sample (next period) observations and the realized returns computed. Clearly, the usefulness of the in-sample weights in terms of producing superior risk-return outcomes are directly related to the inter-temporal stability of the variance-covariance relationships between the various asset classes. Unless it can be demonstrated that such relationships are fairly stable over time, there is, therefore, no guarantee that the weights allocated, or indeed any promising results from previous out-sample data-sets, would necessarily be replicable or reliable indicators of the likely outcomes from applying these weights to a different data set.

The sensitivity of the results with respect to using different data inputs has not being addressed in this Thesis. Nevertheless, it is undoubtedly true that though positive out-sample results are necessary to evaluate the benefits of Managed Futures, they are however insufficient in themselves to guarantee that this is the case. Further research into the issue of risk estimation errors arising from a possible lack of stability in the optimal weights applied to the out sample data would clearly be beneficial. Even so, having promising results is always a good basis on which to begin thinking about the potential benefits of using Managed Futures, especially given the fact that our results are also in line with much of the existing literature regarding the effectiveness of Managed Futures as a portfolio asset.

Fletcher & Hillier (2001) and Michaud (1989) adopt a statistical technique known as re-sampling to reduce the sensitivity of the results arising from the use of different data inputs in the allocation process. Here, re-sampling creates additional returns and new optimization inputs that are statistically equivalent to the original set. A re-sampled set of optimization inputs therefore represents an alternative way history or the future may occur.

One benefit of using the re-sampled efficient frontier is that it moderates the extreme weights that occasionally result from applying a single mean-variance optimization. It does this by generating different efficient frontiers, each of which consists of inputs that are statistically equivalent to the original set. This method improved the robustness of the mean variance approach used by Fletcher & Hillier (2001) and Michaud (1989) in their optimization routines because these different re-sampled efficient portfolios are reduced to a single portfolio that contains the average weights of these simulated "rank-associated" efficient portfolios that consist of the identical statistical distribution property to the original set inputs. The simulation evidence in Michaud (1998) suggests that using re-sampled efficient portfolios leads to improved Sharpe ratio performance compared with traditional efficient portfolios. This is one potentially useful avenue for exploring the sensitivity of the results with respect to different data sets and time periods.

Stevenson (2001) discusses another context in which estimation risk reduction is essential, i.e., the case when minimum risk portfolios are used. Stevenson (2001) explains that the rationale behind the use of the minimum risk portfolios is that the allocations estimated are not dependent on the mean; rather, they are purely determined by the risk parameters. As studies such as Kalberg & Ziemba (1984) and Chopra & Ziemba (1993) have found that estimated allocations are particularly sensitive to variations in the means, the use of the minimum risk portfolio therefore should aid in the reduction of estimation error. A further advantage to the use of the minimum risk portfolio, according to Stevenson (2001), is that studies such as Jorion (1985), Chopra et al (1993) and Stevenson (2001b) have reported that the minimum risk portfolio tends to perform well out-of-sample.

Stevenson (2001) uses several approaches to estimate portfolio performance for a portfolio of emerging market stocks, such as the mean variance approach, Minimum Variance approach, mean-downside risk approach and the minimum downside risk approach. After controlling for estimation risks, Stevenson (2001) reported that the minimum downside risk approach performed better than the other approaches used in out sample tests. It is noted that Stevenson (2001) uses Lower Partial Moment of n=2 for estimates of below target level variation, for his research. The Research of the Thesis has, however, extended beyond Lower Partial Moment of n=2 to include n=1, n=3 and n=4. Even so, the stability of returns is still an issue that could usefully be addressed by further Empirical Research that builds on that undertaken in Chapter 4.

7.3.1.2 Issues relating to the Time Series of Downside Risk

The work of Markowitz (1959) is largely remembered for the stress he placed upon using variance as the primary risk measure. This has profoundly affected the way subsequent academics and practitioners have perceived and evaluated risks. Indeed, the mean-variance framework has been central to the subsequent development of portfolio research, two prominent examples being the development of the Capital Asset Pricing Model and the Generalized Autoregressive conditional heteroscedasticity (GARCH). Both concepts are constructed on the basis of using variance as a risk measure.

What needs to be noted, however, is that Markowitz (1959) was also very much aware of alternative risk measures such as below target-return variance, which he called semi-variance. In fact, Markowitz (1959) considered that analyses based on Semi variance would tend to produce better portfolio outcomes for many investors than those based on variance. Markowitz (1959) explained that an analysis based on variance seeks to eliminate both extremes, while those based on semi variances, concentrates on reducing probable losses, i.e., a greater concentration is placed on reducing losses below target mean returns. Therefore, analyses of portfolios based on semi variance, by concentrating on reducing losses below target mean returns, would then produce portfolios that better reflected many investors risk preferences. It is therefore very unfortunate that, due to the complexity and the computational costs involved at the time, Markowitz (1959) decided to drop semi-variance as his preferred risk measure and to use variance instead for his research on portfolio theory. Even so, Markowitz (1959, pg 194) commented that the current (i.e., late 1950's) superiority of variance with respect to cost, convenience and familiarity did not preclude the use of semi-variance in the future when, as has subsequently happened, computational costs and problems relating to technical complexity diminish due to innovations in information technology. These subsequent improvements in computational and information technology now provide opportunities for more research into the higher moments of the return distribution and to a reconsideration of this and other alternative risk measures within a portfolio optimization framework.

A few studies have already been published using below-target variance as the risk measure, e.g., Harlow & Rao (1989) who test asset pricing in a generalized mean-lower partial variance framework. Their main conclusions from estimations using stock market data is that Lower Partial Moment of degree n=2 appeared to be reflected in market prices. Another study based on below-target variance risk measures is Bond (2000), who showed that the conditional semi-variance of a series could be calculated from the parameters of a double gamma distribution. Estimates of conditional downside risk based on the double gamma model were then constructed for each series of foreign currency, including the US Dollar, Deutsche Mark, French Franc, Swiss Franc, Japanese Yen, Colombian Peso, Greek Drachma, Korean Won, Malaysian ringgit and the Zimbabwean Dollar. Bond (2000)'s results reveal that for the Malaysian Riggit, Zimbabwe Dollar and the Korean extreme downside volatility were experienced during the recent emerging markets currency crisis. Further work along these lines would clearly be of value in evaluating the potential benefits of Managed Futures.

Further research on exploring the time series properties of semi-variance and the effect on portfolio optimization from using Lower Partial Moment and other alternative formulations of risk may, however, be hampered by the lack of high frequency data. This is because the highest frequency data currently available in relation to Managed Futures is only on a monthly basis. It is strongly believed that higher frequency data, such as weekly or daily data, as is available for most other asset classes, may be required for further research in this area.

7.3.1.3 Issues on other Risk Measures related to Below-Target-Level variation

The analysis of Chapter 4 linked skewness with downside risk modeling (see the review by Nawrocki, (1999)). However, it is also found that downside risk has gained increasing attention due to academic and practitioner interest and awareness on the use of value-at-risk (VaR) models. VaR measures the worst expected loss under normal market conditions over a specific time interval at a given confidence level. For example, if a portfolio manager has a daily VaR equal to 1 million pounds at 1%, then this means that there is only one chance in a 100 that a daily loss bigger than 1 million pounds occurs under normal market conditions.

Duffie & Pan (1997) provide a good review of this topic. They see the rationale of using VaR from the perspective of asset allocation, to the extent that expected end-of- year loses are lowest at 1% probability levels. Therefore having an asset within the portfolio with a distributional pattern of positive skewness would be helpful. This is because having positively skewed assets in a portfolio (see Nawrocki, 1999), implies that upside returns will be of a larger magnitude than the maximum expected downside returns (and when losses occur, they will be smaller and when gains occur, they will be greater). Huisman, et al (1999) and Amy (1999) provide good reviews of the use of VaR within an asset allocation or optimization framework.

To capture skewness more effectively within a portfolio, Lamm (2003), for example, incorporated VaR ideas within his optimization routine for portfolios that consisted of assets with non-normal returns distributions, by incorporating Cornish-Fisher expansions in the framework. Further research on VaR-based optimization models in the effective allocation of assets within portfolios using Managed Futures would appear therefore to be another promising possible development.

7.3.2 Future Research in respect of the Analyses Addressed by Chapter 5

7.3.2.1 Issues Relating to the Stability of Returns

The issue of the stability of returns takes a different form in this Chapter. Chapter 5 used portfolio optimization with respect to the use of time varying or conditional variances. The discussion regarding the stability of returns has so far not addressed concerns such as the sensitivity of the results with respect to the data inputs used for optimization. In this Chapter we modeled the conditional variances in a time series framework and, clearly much more work would have to be done to determine the stability of returns. In short, this would involve tests of the sensitivity of the parameters involved in specifying the time varying variables, with respect to the data inputs used.

Pojarliev & Polasek (2001) provide a good review of this type of research, showing how the results of portfolio construction that incorporate conditional variances, can be made more robust and stable by using Bayesian GARCH forecasts. As the Research of this Thesis focuses not so much on issues about the specification and estimation of the models, these issues are therefore left for future research.

7.3.2.2 Issues on Model Specifications

The Chapter was also interested in evaluating the use of Managed Futures as a cushion against volatility and shocks. The time varying variance is modelled with the aim of minimizing this variance. We adopted a bivariate GARCH (1,1) model in this case, in which the co-movement of the underlying pairs of assets time varying variances were calibrated. The initial idea for the Chapter was to model different degrees of market volatility and market interdependencies using three different GARCH(1,1) models to determine the usefulness of Managed Futures. Unfortunately, two of the multivariate GARCH models, the BEKK and the Vech models did not appear to be well specified and they were not included in the Chapter and therefore the analysis simply concentrates on the Constant-Correlation-Bivariate GARCH(1,1) model. The BEKK and the Vech models, however, are the two models that can explain market interdependences more precisely as they take into account asymmetric patterns of volatility and volatility spill over effects. More details on the BEKK and the Vech approaches to model the GARCH process can be found in Baba, Engle, Kraft & Kroner (1991) and Bollerslev, Engle and Wooldridge (1988) respectively.

As the GARCH Model is a nested model, its specification becomes an important issue. One example is the generation of the residual series from the conditional means equation that use the auto-regression. It is realized that there were arguments regarding the relevance of the type of curve fitting tests needed with respect to the distribution pattern of the residual series. According to Choudhry (1996) and Bollerslev et al. (1992), if the stock returns exhibit non-normal unconditional sampling distributions, they will produce skewness and excess kurtosis. However, as shown by Baillie and DeGennaro (1990) and

Bollerslev (1987), the distribution assumption of conditional normality may be inappropriate if the residuals series are leptokurtic. In such cases, the assumption of a conditional student-t density may be more appropriate. Choudhry (1996) used both the conditional normality and the t-density estimations. Both estimation approaches, however, produced similar results. The observation of the residual series reveals the presence of skewness and kurtosis for the three market Indexes. According to Joseph (2003) there is no conclusive evidence on the statistical distribution that is most likely to provide the best fit for univariate GARCH modelling. Hence, alternative estimations based on conditional student t-density test were therefore not undertaken since the univariate GARCH model is quite well specified for the 3 market Indexes. Nevertheless, further research along these lines is perhaps warranted.

Having reviewed the literatures, the misspecification of the BEKK and the Vech approaches to Multivariate GARCH modeling might have arisen from the use of the conditional normality assumption when fitting our model. Monthly data were used for the studies which is the same frequency data as in Choudhry (1996), Joseph (2003) and Baillie & DeGennaro (1990). It is not clear if or how the results from modeling BEKK and Vech approaches to multivariate GARCH will be affected by using the conditional t-density approach. However, this is a worthwhile topic for further research, especially if more detailed results on market interdependencies, such as the volatility spill over effects of Managed Futures within a portfolio, arose.

7.3.3 Future Research in respect of the Analyses Addressed by Chapter 6

7.3.3.1 Issues on other Technical Trading Strategies and Specifications

The main contribution of Chapter 6 comes from the increased knowledge of the mechanics and return profiles of the off-shore US Dollar based Managed Futures funds. Clearly, being located off shore provides more flexibility to CTA's, and one possible area in which they could expand their operations would be to explicitly market their funds to non-US investors as an active-currency-based asset class. As there is already a significant academic literature that provides some evidence of improved performance using Active Currency Management strategies (or conditional hedging) relative to using unconditional forward contracts or spot rates, this was the focus of the analysis in Chapter 6.

The tentative evidence of the potential benefits available for Active Currency Management for portfolio with Managed Futures suggests that further research may be required in order to be confident that it is possible to exploit such location arbitrage opportunities available to the off shore Managed Futures specialists. For example, enhanced portfolio UK£ returns may be possible by applying relatively well-specified trading strategies incorporating off shore Managed Futures with Active Currency Management.

Other potentially fruitful avenues for future research include exploring different forms of trend following rule used as the basis for "buying" and "selling" decisions and/or hedging criteria. Some examples along these lines include Pollock, A.C, Macaulay, Thomson, M.E and Dilek, O-Atay (2003) and MacDonald, R and Norbert, F (1999). The former used estimated probabilities, instead of prices, to trigger buying and selling decisions, while the latter focused on using co-integration of intra-day (i.e., opening, highest and closing prices) prices to signal buying and selling decisions.

The three different moving averages methods (i.e., the Simple Moving Average, Linearly Weighted Moving Average and Exponential Moving Average) gave rise to the same signals in some instances, regarding whether or not to hedge the currency exposure (which resulted in identical returns). This could be due to the particular characteristics of the dataset and time period used in our analysis. It could also mean that the approach does not capture variation very well for the dataset used and a re-specification of the moving average function might be needed. This is clearly another potentially fruitful area for future research.

Finally, investigating how the use of Active Currency Management might affect UK investors within a multi-currency portfolio framework might also be considered, since this research focused only on a single currency portfolio.

7.4 Concluding Remarks

This Thesis has investigated the development of the Managed Futures industry and has attempted to provide an empirical analysis of the likely benefits of including Managed Futures within an internationally diversified UK portfolio. The analyses have treated Managed Futures as an asset class. Viewing Managed Futures as an asset class indicates that traders have an underlying profit motive. This is different from the traditional way of dealing with financial or commodity futures instruments, which views them as predominantly hedging tools. We have provided empirical evidence which indicates that Managed Futures have the potential to generate relatively better portfolio returns and may also help to reduce portfolio volatility. Therefore, treating Managed Futures as an asset class does appear to have the potential to add value to UK investor portfolios.

In the UK, more significant developments in the future in this and related areas are to be expected. This is because, even though the off-shore US Dollar based Managed Futures industry is well developed, the Financial Services Authority (see FSA, 2002, 2005a and 2005b) of the UK, at the point when this thesis was submitted, remains keen to develop the on-shore hedge fund market, of which Managed Futures is an important subset. The findings presented in this Thesis may therefore serve as an important source of information regarding the different aspects of Managed Futures investing.

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