

Ph.D. Thesis

**OPTIONS IN EMERGING MARKETS: EVIDENCE FROM THE GREEK
DERIVATIVE MARKET**

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Abstract

Index options are traded in many derivatives markets around the world. These derivatives markets can either operate in efficient or inefficient markets. Most derivatives markets use the best known option pricing model, i.e. the Black and Scholes Option Pricing Model, in order to produce theoretical option prices. However, the model itself assumes that the markets are efficient so that theoretical prices do not differ significantly from market prices. But what is happening in emerging markets? Emerging markets are characterized by many anomalies, which may create problems either to the model or in general to the fair option pricing.

This study is concerned with the Athens Stock Exchange and the Athens Derivatives Exchange. Specifically, this research tests the at-the-money index call options on the FTSE/ASE 20 index with two months to expiration.

The Greek market is an 'emerging' market and this research tries to show that the Black and Scholes model is not an appropriate model for the Athens Stock Exchange or, more generally, for emerging markets, due to its assumptions. Additionally, the research tries to identify market anomalies and to test whether these anomalies have a significant effect on the market option prices.

The thesis includes a review of empirical studies on stock and option markets and on the Black and Scholes model. The conclusions of these studies suggest that there are several market anomalies in stock markets that affect option prices. Furthermore, there are many criticisms that can be leveled against the Black and Scholes model and its assumptions.

In order to identify the market anomalies and option mis-pricing, we employ a battery of statistical tests. The test results tend to support the previous empirical

studies and suggest that the Athens Stock Exchange suffers from several anomalies. The results also indicate the inefficient status of the market. In addition, the Black and Scholes model creates pricing problems in the Greek market. These pricing problems are due to the stock market anomalies and the mis-estimation of the true (historic) volatility from the implied volatility.

The final part of the thesis shows the significant effect that the stock market anomalies have on option prices. Market anomalies, such as mis-estimation of the historic volatility, asymmetric information, insider trading and low market depth, have a significant effect on option prices. Adding these anomalies to the Black and Scholes model, we are able to construct a model that can predict market option prices more reliably.

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CHAPTER 1: Introduction

1.1. Introduction

In recent years, investment behaviour, techniques and choices have been changing, as economies around the world have become more inter-related and so come to affect each other to a greater degree than previously. A prime example is the European Union (EU), which has united most member states as they target greater economic efficiency. This process of globalisation has advantages and disadvantages. Starting from the disadvantages, we can say that market risk is the greatest of all. For example, the under-performance of a strong economy (e.g. the US economy) could create significant problems for other countries. However, on the opposite side, the greater degree of correlation between economies creates opportunities for producing greater wealth and becoming stronger.

On a smaller scale, the greater correlation of the world's economies forces their stock markets to become more correlated as well (Obaseki and Okafor, 2000, Nwokoma and Olofin, 2003). The high correlation in stock markets also creates benefits and drawbacks. One benefit is that institutional investors' funds are being invested in many markets that previously would not have been considered. Examples of such markets are the stock markets of emerging countries, such as those in Eastern Europe. However, this high correlation also has drawbacks for investors, one of which is a lower diversification opportunity, which means that there are fewer opportunities for risk reduction.

Investors have to work out how to earn profits from this transition of the world economy. Nowadays institutional and non-institutional investors have to become

global in order to explore all the opportunities on offer. They must become global in order to avoid threats as well, as stated above. However, how can they avoid the threats that globalisation can create? A possible answer to that question is through the exploitation of the investment choices offered by the larger number of markets available. New investment tools can provide reduction in risk or higher profits. Additionally, established tools that are introduced in new markets can also provide the same opportunity. Such investment tools are the derivatives.

Derivatives are instruments with characteristics that comprise both the opportunity for lower risk and greater profits. A derivative is an instrument whose value depends on the value of other variables, such as stocks, indexes, interest rates, treasury bills etc. In other words, the value of the derivative depends on the value of the underlying asset (Wilmott, 1998). There are many kinds of derivatives such as futures, forwards, swaps and options. In this research, we focus on options rather than the whole field of derivatives.

Options are derivatives that give the right to the buyer to buy or sell a predetermined quantity of the underlying asset from or to the writer of the option. The writer then has the obligation sell or buy the underlying asset to or from the buyer. Options are divided into two categories: calls and puts. Call options give the right to the holder (buyer) of the option to buy the predetermined quantity of the underlying asset from its writer, meaning that the writer has the obligation to sell the underlying asset. Put options give the right to the buyer of the option to sell a predetermined quantity of the underlying asset to the writer of the option. So the writer has the obligation to buy the underlying asset (Wilmott, 1998; Hull, 1997; Bryis et al, 1998, Chance, 1998). If the option is American then it can be exercised during the whole

period of the option's life, while if the option is European then it can be exercised only on the last day of the option's life.

Options offer greater leverage, risk reduction (hedging) and arbitrage opportunities. These opportunities can be exploited only if the options are combined with other variables, such as stocks, indexes or interest rates, or if they are combined with each other. These two kinds of combinations are called option strategies.

There are many option markets around the world such as the London International Financial Futures and Options Exchange (LIFFE) and the Chicago Board Options Exchange (CBOE). However, as well as the option markets that operate in mature economies, there are some that operate in emerging markets, such as the Athens Derivatives Exchange in Greece.

1.2. An outline of the characteristics of emerging markets

Emerging markets are those markets that operate in countries that are in a transition period and are trying to improve their economic status in order to reach the standards of the more developed countries. Emerging countries tend to receive funds from sources such as the International Monetary Fund, the World Bank or, specifically for the European countries, from the European Central Bank and the Communal Support Framework. Such funds in emerging economies may make international investors favour emerging markets due to the potential of high profits. However, we must not forget that such markets do have a high level of risk as their stocks, bonds and other investment instruments experience high fluctuations in their prices.

As a result, emerging markets are usually considered to be inefficient and the inefficient operation of a stock market can create several problems for the associated derivatives markets for the following reasons:

- Share prices might not be at their fair value, meaning that there could be over- or undervalued share prices in the market giving rise to arbitrage opportunities for some investors, especially for institutional investors.
- Emerging markets experience greater fluctuations than mature markets causing very high spreads between the highest and the lowest share or index prices.
- Indexes are not very strong meaning that their fluctuation depends on the fluctuation of only few stocks. These indexes can easily collapse as only a few stocks need to underperform, rather than the whole stock market.
- Indexes sometimes are constructed in such a way that they do not reflect the stock market's behavior as a whole. This is in addition to the above point. The stocks that comprise an index usually are the best stocks rather than a sample of all the stocks that are listed in the market. So the 'picture' that the indexes show is not the one that would be portrayed if indexes were better structured.
- The flow of information is not efficient as most of the information is known only to a small group of investors. Usually in all stock markets, but much more in emerging stock markets, investors are informed by means of the

financial press or free internet sites. However these investors do not have access to the information that the brokers have or other 'insiders'. Additionally, several media tend to support some stocks and so tend to provide information only for those stocks.

- There may be a high incidence of insider trading, which can be very costly for non-institutional investors. We argue that insider trading can be very costly as insiders have private information that other investors do not have. So private and institutional investors, who have access to the private information, can sell at high levels and then buy at low levels. The profits that they generate are losses for the remaining investors.

- There may be high transaction costs, e.g. the high cost of re-hedging. High transaction costs leave several investors outside the stock market as they look to place their funds to cheaper stock markets. Furthermore investors cannot hedge their risk any time as the cost of re-hedging is higher than the actual benefit of the hedge. (Wilmott, 1998; Hull, 1997; Bryis et al, 1998; CBOE, 1999; ADEX)

These characteristics cause problems in option markets. They are problems that are related to fair value and other pricing problems, performance and returns, and market efficiency. But option markets can play another role, that of reducing some of the market inefficiencies.

Derivatives are not only of interest to the investors, but have also become a source of inspiration for researchers and practitioners to produce research studies. These studies are either theoretical or empirical in content.

This study tries to achieve two goals. The first is to add to the existing literature further information in the field of index options, which are traded in emerging markets. The second purpose is to provide evidence that market anomalies have a significant effect on option prices and in addition that some of the assumptions of the world's best-known option pricing model, the Black and Scholes Option Pricing Model (BSOPM), do not hold.

The market under examination is the Athens Derivatives Exchange, so we start by presenting some information regarding this market and its underlying market, the Athens Stock Exchange (ASE).

1.3. The Athens Derivatives Exchange

The operation of the derivatives market in Greece is controlled by the Athens Derivatives Exchange SA (ADEX) and the Athens Derivatives Clearing House SA (ADECH). ADEX and ADECH were established in April 1998 and operate in accordance to the Law 2533/77. The Capital Market Commission is responsible for the control and supervision of the operation of ADEX and ADECH. ADEX is responsible for the organisation and support of the derivatives market and for the supervision of trading on a series of standard contracts, such as futures and options, and is also responsible for the overall development of the derivatives exchange. ADECH is responsible for the recording, clearing and provision of guarantees for all

types of transactions in ADEX. ADEX has share capital of €9 million (i.e. 3,000,000 shares with a nominal share value of €3 each)

The derivative products that have been introduced are contracts based on various financial assets, such as stocks, stock indices, interest rates and bonds. Their value, performance and return depend upon the underlying asset on which they are based. In ADEX, three types of futures contracts are traded: futures on the FTSE/ASE 20 Index, futures on the FTSE/ASE Mid 40 Index, futures on the 10-year Hellenic Republic Bond, options on FTSE/ASE 20 Index and Stock Lending contracts.

The option contracts on the FTSE/ASE 20 started on 11/09/2000 and so at the time of writing, they have had just over 3 years of life. The index options on the specific index are still in an infant stage due to their short existence. The following research will use ADEX as the market under examination and the option type under examination will be the index option on the FTSE/ASE 20. The option contracts in ADEX are European-style options, meaning that they cannot be exercised prior to their maturity.

The short history of the ADEX does not allow us to conduct an in-depth analysis of its performance. However, the evidence so far seems very encouraging. In Table 1.1, we are able to observe that the market is growing in demand as the number of investors in 1999 was only 325, but this had grown to 15,482 by the end of 2002. This is an increase of more than 46 times. Furthermore, in these four years of operations the ADEX market has developed eight traded derivatives. These derivative instruments are the futures in the FTSE/ASE 20 index and in the FTSE/ASE 40 index, futures in the 10 year government bond and specific stocks, options in the FTSE/ASE 20 and 40 indices and options in repos and specific stocks. In 2003, two more products will enter the market, futures and options in the EUR/USD exchange rate.

With regard to option contracts, we can see from Table 1.1 that there has been an increase in transaction volumes and values. At the end of 2000, when options were first introduced, the transaction volume reached 26,052, but by the end of 2002 the transaction volume had increased to 1,013,194. This is a massive increase of almost 38 times. The same pattern is observed in the transaction values of traded options. During the three years of operation, values increased by 20 times: in 2000 the figure was €276.12 million and at the end of 2002 was €5,774.86 million (see Appendix 1).

Table 1.1: Transaction Volumes and Values for ADEX (1999-2002)

	1999	2000	2001	2002
Number of Investors:	325	3,181	9,133	15,482
Products	1	5	7	8
Transaction volumes		26,052	287,055	1,013,194
Transaction value (nominal values, €m)		276.12	2,255.1	5,774.86
Transaction value (based on the premium, €m)		9,6	110,51	402,61
<i>Source: Athens Derivatives Exchange</i>				

Despite the increases in the above indicators, ADEX is still an emerging derivatives market due to its short life and the very low value of transactions that take place on it compared to the ASE, where transaction values reached a level of €24,784 million in 2002. The ratio between the transaction values of the ADEX and the ASE is about 5 in favour of the ASE.

1.4. The Athens Stock Exchange

1.4.1. A brief history of the Athens Stock Exchange

In 1870, above the café ‘The Beautiful Hellas’ there was the office of the Athens Merchant Club. The merchants used to meet in this club in order to discuss various issues and to negotiate the two National Bonds that were issued at that time. In October 1872, the Credit Bank was established and in March 1873 and May of the same year, the Lauriou Company and the Industrial Credit Bank of Greece were established respectively. These establishments led to more intensive transactions, more speculation and so the Athens Merchant Club was renamed as the ‘*Stock Exchange*’ (Voulgari, 1995).

The Athens Stock Exchange was established in September 1876 under the Koumoundourou government (Voulgari, 1995). In this year, there was the issuance of the first Stock Exchange Law based on the French Commercial Code. Under Law 2324/95, the ASE was reformed from a Corporate Body under Public Law to a Société Anonymé with the name of Athens Stock Exchange S.A. (Fact Book, 1999). The duration of the company was set to be 200 years. This duration could be extended or become shortened only if the General Meeting of the Shareholders decided it (Voulgari, 1995). Now the ASE is located at 10 Sofokleous Road. It is very common in Greece to refer to the ASE as the ‘Sofokleous’.

1.4.2. Overview of the Athens Stock Exchange

The ASE is an organisation that nowadays is known to almost the whole Greek population, and a significant percentage of the population invests on it. However, a decade ago only a minimal percentage of the Greek population knew what it meant to invest on the stock exchange and almost no foreign investors (private or institutional) were involved with investments on the ASE.

Yet since the early 1990s, many changes have taken place in Greece and in the ASE. The whole Greek economic and political climate has changed through the years, resulting to a new investment environment. The improvement of the Greek economy and the creation of a stable political climate have helped in the development of a more secure capital market that is recognised all over the world. It is notable that for two consecutive years (1997 and 1998), the ASE was the best performing stock exchange in the world.

The reformation of the ASE was an important result of the improvement of the macroeconomic and political environment in Greece. During the 1990s, the ASE made changes that were mainly concerned with the statutory context of the ASE. In particular, a more comprehensive and advanced operational and trading system and legal framework was established. These changes offered to the ASE the opportunity to improve its performance and to attract interest from both domestic and foreign investors.

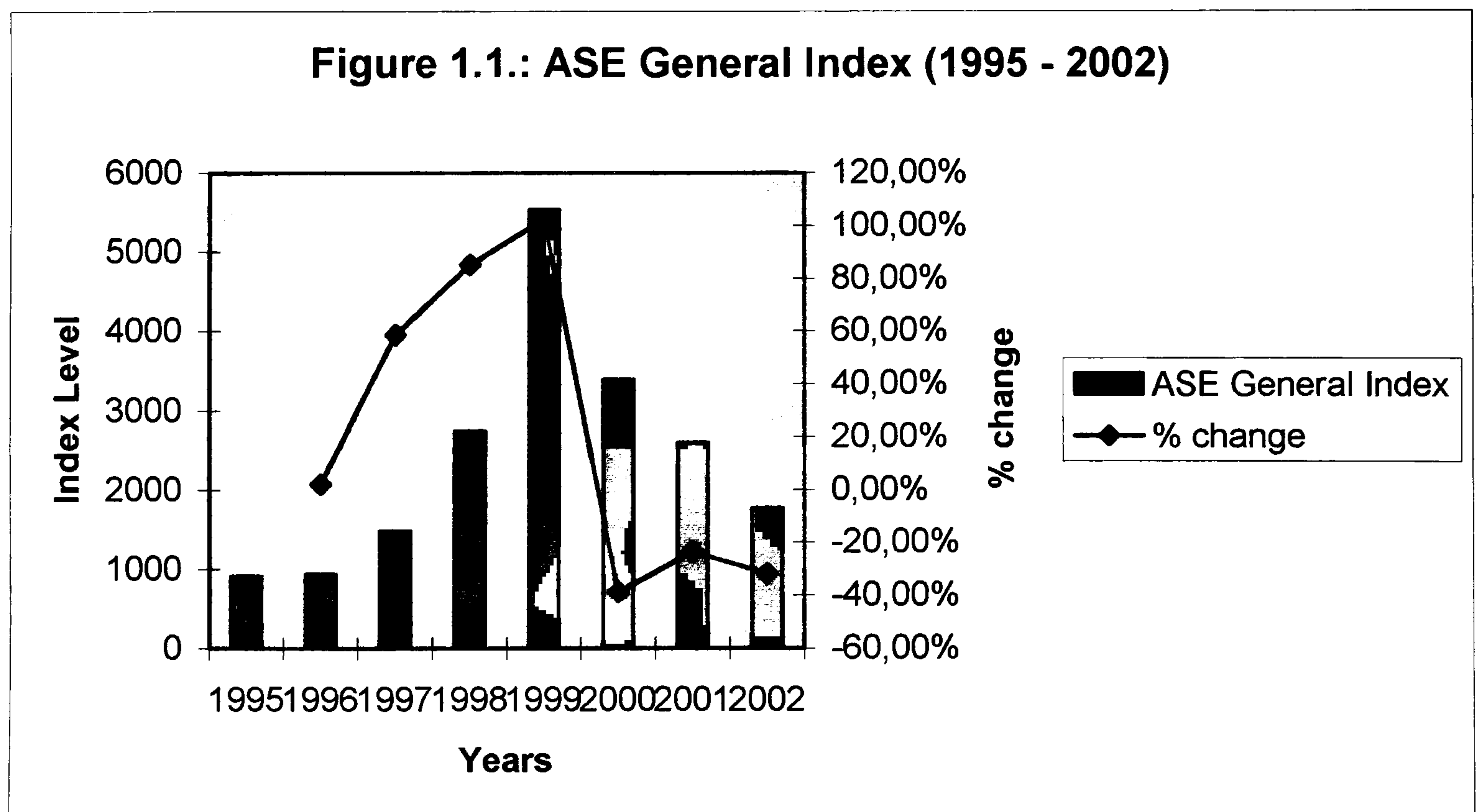
From 1995 to 1999, the market rose by 505%. In the next few years, the ASE under-performed and by the end of 2002, the ASE General Index was at the level of 1762.69, i.e. it had suffered a 68% drop from the level of 1999. Furthermore, the same pattern is observed in the transaction values and in the market's capitalisation. The

high capitalisation index, FTSE/ASE 20 index, has also dropped since 1999. As shown in Table 1.2 and Figure 1.1, the index dropped by 70% from 1999 to the end of 2002. (See also Appendix 2).

Table 1.2: ASE General Index (1995-2002)

<i>Years</i>	<i>ASE General Index</i>	<i>% change</i>
1995	914,15	
1996	933,48	2,11%
1997	1.479,63	58,51%
1998	2.737,35	85,00%
1999	5535,09	102,21%
2000	3.388,86	-38,77%
2001	2.591,56	-23,53%
2002	1.762,69	-31,98%

Source: Athens Stock Exchange



It could be said that in 2001 the ASE entered the league of the mature markets. However, as shown in Table 1.3, it still retains some of the characteristics of emerging markets, such as low transaction values, high concentration of market capitalisation in a small amount of stocks and low liquidity.

Table 1.3: Concentration and Liquidity in the Greek and UK Stock Markets

Years	Concentration Ratio		Liquidity Ratio	
	Greece	UK	Greece	UK
2000	0.46	0.25	0.94	3.01
2001	0.47	0.26	0.47	3.66
2002	0.60	0.32	0.40	4.00

Data from ASE and LSE (actual figures are in Appendix 3)

The concentration ratio for the ASE is high and indicates that 46%, 47% and 60% of the total market capitalisation over the period 2000-2002 came from the 10 largest stocks. The number of listed firms for the same period was 342, 349 and 348 respectively. Comparing these figures to the UK ones, we can see how concentrated the Greek stock market is. Furthermore, market liquidity is relatively low for the Athens Stock Exchange. The liquidity ratio can be found by dividing the transaction values by the market capitalisation. The ratio should be at least 1, meaning that a market has normal liquidity if the market capitalisation is transacted at least once during a year. For the Greek stock market the ratio is 0.94, 0.47 and 0.40 for the period under examination. The UK statistics respectively are 3.01, 3.66 and 4. So, from these results we can see that there are stocks for the Athens Stock Exchange that remain untraded. The main reason for such results is that investors do not have the liquidity in order to enter the market and to make transactions. Of course, this can also be concluded from the transaction values that have been declining since 1999.

1.5. Description of the thesis

From the overview of the ADEX and ASE, we are able to see that both markets seem to be emerging. ADEX has very low transaction values compared to the underlying market (ASE) and the ASE has a high concentration ratio and very low liquidity.

The thesis attempts to identify and estimate the significance of the stock and derivatives markets' anomalies on option contracts and specifically on the valuation of these contracts. The study will concentrate on at-the-money call options on the FTSE/ASE 20 index (see Appendix 4), with two months expiration time, for the period 9/2000-9/2002. A detailed analysis of the variables and data is included in the methodology section in Chapter 5. The main reason for choosing at-the-money call option contracts with 2 months expiration time is that these series are considered to be the most heavily traded and thus should provide the best answers to our research questions. The anomalies to be examined in the thesis are asymmetric information and insider trading in the ASE, the market depth of the ASE and ADEX (in terms of transaction volumes and transaction costs), seasonality and calendar effects, the non-normality of the series under examination and the mis-approximation of implied volatility.

The study starts with an analysis of the EMH, CAPM and BSOPM. A review of some empirical studies regarding stock and derivatives markets' behaviour will follow. The thesis then turns to the main part of the research: the empirical study. First, some tests will be conducted regarding the anomalies of the ASE and ADEX that could cause problems to the BSOPM. Specifically, we test the efficiency level and the normality of ASE and the put-call parity. Then there will be tests regarding the validity of the BSOPM in markets like the ASE and ADEX. Having generalised the conclusions on these tests, we will move on to the last part of the thesis in which we will estimate and identify the significance of the market anomalies on option prices and whether these anomalies create mis-pricing of option contracts.

A more detailed explanation of each part of the thesis follows.

1.5.1. Outline of chapters

An outline of the remaining chapters is essential in order for the reader to know how the study will be structured.

In CHAPTER 2 there is an analysis of the Efficient Market Hypothesis and the Capital Asset Pricing Model. The analysis is focused on the assumptions of the models.

In CHAPTER 3 there is an extensive analysis of the BSOPM. The analysis includes an explanation of the model and the main criticisms of it.

CHAPTER 4 comprises a literature review of the empirical studies on option and stock markets. These studies mostly refer to stock market anomalies and the relationship between stock and option markets.

CHAPTER 5 presents the methodology and will describe the methodological approach and research methods that are used in the thesis. In addition, this chapter includes a thorough analysis of the variables that are used in the study.

In CHAPTER 6, we present the tests that have been conducted in order to identify anomalies in the ASE that could create problems in the BSOPM. These tests are divided into efficiency testing and tests that show whether ASE is a proper market for normal theory models. Additionally, there are tests regarding the validity of the BSOPM in an emerging market, such as the ASE, and finally there are tests regarding the efficient operations of the ADEX. The main findings reported in this chapter are:

- the FTSE/ASE 20 index is not efficient.
- Implied volatility is not a good approximation for true volatility.

- Overall the index and the log-index are not normally distributed despite the fact that the trading which is taking place with two-day's break (i.e. Friday – Monday) is normally distributed.
- Put-call parity does not hold, yet when transaction costs are incorporated there are no arbitrage opportunities.
- The BSOPM provides prices that are significant different from the market prices.

CHAPTER 7 is one of the most important chapters as we test whether the anomalies that have been observed in the ASE and ADEX are significant and if they create mis-pricing problems in option contracts. The main findings of this chapter are:

- Transaction costs have a significant effect on option prices.
- Asymmetric information affects option prices.
- Option transaction volumes affect option prices.
- Tests on the final regression model show that the model generates better results than the BSOPM. They also show that the model has good predictive ability. Finally, tests show that asymmetric information, transaction costs and option transaction volumes all have significant effects on option prices.

Finally, CHAPTER 8 is the last chapter of the thesis, which draws conclusions and makes recommendations for future research.

1.6. Conclusion

In brief, we can say that this study is concerned with the use of index options in emerging markets. The study focuses mainly on the mis-pricing of such options, especially in emerging markets, which can provide abnormal profits to some investors

and serious losses for other investors. Before the analysis and presentation of the literature review and tests, we consider in detail the efficient market hypothesis and the capital asset pricing model (in Chapter 2). We then turn in Chapter 3 to the main model under examination, the BSOPM.

CHAPTER 2: Efficient Market Hypothesis and Capital Asset Pricing Model

2.1. Introduction

In this chapter, we present and analyse the Efficient Market Hypothesis (EMH) and the Capital Asset Pricing Model (CAPM). We focus on the EMH as it is one of the most fundamental assumptions in any pricing model. The EMH is also one of the most controversial issues in finance. On the other hand, CAPM is the most widely known and used pricing model for assets. CAPM shows the relationship that must exist between risk and return, if markets are efficient.

CAPM refers, as we will see below, to the relationship between risk and return, while EMH refers to the response rate of the asset price to the arrival of new information in the market. So the question that EMH is asking is: how quickly do stock prices reflect new information?

As we mentioned above, efficiency is a major assumption in all pricing models, including the BSOPM. The analysis of the EMH will assist us to understand the consequences of inefficiency in a market and how this can affect asset pricing models.

Finally, CAPM will assist us to understand the risk-return relationship, which again applies to all pricing models, including the BSOPM.

2.2. Efficient Market Hypothesis

One of the most fundamental concepts in finance is the Efficient Market Hypothesis (EMH) which was introduced by Fama (1965, 1970). Since its first appearance, the EMH has been an issue for debate between academics and professionals.

The EMH argues that a market is efficient only when many rational investors are competing with each other by analysing market information in order to maximize their profits. Fama (1965, 1970) showed that there are three different categories of market efficiency.

Strong Form: Strong-form efficiency implies that, at any given time, the share price reflects all available information, whether it is publicly available or not. So even information from inside a company cannot offer an investor excess returns, as the information has already been reflected in the share price. So if the ASE were strong-form efficient, we would expect that private information would not be able to generate higher returns for insiders. In other words, if asymmetric information arrived in the market, there should not be any abnormal rises or falls in the index's returns (Seyhun, 1998)

Semi-Strong Form: In a market that is semi-strong efficient, share prices incorporate all publicly available information. According to this form of efficiency, fundamental analysis is pointless. Fundamental analysis tries to analyse the movement of a share price in relation to publicly available information. However, as the information is already reflected in the present share price, an investor cannot earn excess returns

based on these observations and calculations. Hence if the ASE is semi-strong efficient, we would expect to be able to estimate true or historic volatility from implied volatility. Additionally, the index should not appear to have any volatility clustering (ARCH and Generalised ARCH effects), as volatility clustering could be used to predict future prices of the index (Panagiotides, 2003).

Weak Form: Weak-form efficiency implies that, at any given time, all past price movements are reflected in the share price. So technical analysis is of no use as technical analysis takes into consideration only past prices. However, as those prices are already incorporated in the share price, investors cannot earn excess returns. If the ASE were weak-form efficient, then one would expect to find that the FTSE/ASE 20 index would follow a random walk and the index returns would be uncorrelated and independent (Wheeler et al, 2002).

In short, the EMH states that no investor can constantly outperform the market if the market is efficient. However, investors sell stocks that they believe are worth less than their current prices and they buy stocks that they believe are worth more than their current prices. According to EMH, this cannot be profitable. One can conclude that trading financial assets in order to outperform the market is not a matter of skill but rather a matter of luck.

Another implication of the EMH is that as most of the investors are rational and believe that the market is efficient, and that nobody can outperform the market, there is no point in trying to analyse the market's information and stocks. But if this were the case, i.e. if there were no information analysis, then markets would no longer be efficient as stock trading would depend solely on luck.

Many researchers have tried to identify anomalies in stock markets and to challenge EMH. These studies have tried to show that there are markets that are not efficient due to certain anomalies. These anomalies can be summarised as fundamental anomalies, such as low price to book value, meaning that stocks with low book to market value outperform those with the high book to market value (Fama and French, 1992, Dennis et al, 1995). Other anomalies include calendar anomalies, such as day-of-the-week effects (e.g. the result that Mondays have lower returns than other weekdays (Harris, 1986, Agrawal and Tandon, 1994), month-of-the-year effects (e.g. the result that January stock returns are the highest of all months (Haugen and Jorion, 1996, Bhabra et al, 1999) and turn-of-the-month effects where it has been shown that stock returns are higher on the last days of a month and the first few days of the next month (Hensel and Ziemba, 1996). Other anomalies include the small business or size effect where it has been argued that small firms outperform larger ones (Reinganum, 1997), and ‘insider transactions’ effects, according to which the observation by investors that insiders are trading their stocks is seen as a signal that the stock price will rise (if insiders buy) or that it will fall (if insiders sell) (Fishman and Hagerty, 1992). In addition several other anomalies have been identified in capital and stock markets which provide evidences against the EMH. Such anomalies include the S&P index effect (Harris and Gurel, 1986, Shleifer, 1986) where firms which are about to be included in the S&P index, they tend to have a huge rise. Furthermore another anomaly is the pricing of closed-end funds (Lee et al, 1990, Lee et al, 1991) where these funds tend to trade at a discount relative to their net assets values.

Finally, a theory that tries to challenge EMH is that of ‘behavioural finance’. Behavioural finance deals with the influence of psychology in financial decisions and argues that factors such as fear, greed, risk seeking and peer group pressure have an

important role in investment considerations. According to Barber and Odean (1999), investors make two mistakes. The first one is excess trading and the second is the tendency to disproportionately hold on to losing investments while selling winners. They argue that these mistakes have a systematic character and are not random. As they have a systematic character, Barber and Odean (1999) argue that these mistakes are made due to psychological factors. Another study by Hirshleifer (2001) argues that financial decisions are made not only under the examination of new information but also based on the investors' psychology for the stock prices. In addition, Barberis (2001) points out that investors' behaviour is a major consideration for decision making and thus there should be models which can capture investors' behaviour in asset pricing.

Fama (1998), however, argues that despite the fact that stock prices over-react and under-react to new information, which is a result of psychological factors, this does not mean that EMH does not hold. Fama (1998) based his argument on the fact that most of these reactions tend to disappear in the long-run.

In Chapters 6 and 7 a number of tests are applied to check for efficiency. These are summarised below.

Strong-Form Efficiency: Tests for insider trading and asymmetric information are used. These are chosen as in a market with strong form efficiency, inside information should not yield abnormal profits due to the fact that all information (even inside information) is incorporated into the stock price.

Semi-Strong Form Efficiency: We use volatility tests to check for semi-strong form efficiency. These tests have been chosen as if all publicly available information is at

the disposal of all investors, then implied volatility will not be significantly different from the historic or true volatility. In addition, if the ASE is semi-strong efficient, there should not be any volatility clustering. If all publicly available information is not incorporated into the stock price, then investors will be able to use fundamental analysis.

Weak Form Efficiency: To test for weak-form efficiency, we use a random walk test, a runs test and seasonality tests (i.e. tests for day-of-the-week and January effects). We argue that these tests can assist us to check whether the ASE is a market with weak-form efficiency as they all show whether the market's returns follow any specific patterns. If they do, then technical analysis can be used to explore those patterns and earn excess returns.

Finally many financial models are based on an assumption regarding EMH. These models assume that markets are efficient in order for them to work. One of these models is the Capital Asset Pricing Model.

2.3. Capital Asset Pricing Model

2.3.1. The model

In order to analyse CAPM we first need to introduce the model and state its assumptions. CAPM was introduced by Treynor (1961), Sharpe (1964) and Lintner (1965). CAPM divides the risk of holding assets into systematic and unsystematic risk. Systematic risk is the risk of holding the market portfolio. This risk is incorporated into the stock as each stock participates in the market and so to a smaller

or greater extent stocks are affected by the market. Unsystematic risk is the risk which is unique to an individual asset. It represents the component of an asset's return which is uncorrelated with general market movements. Unsystematic risk is the risk that can be diversified by creating a portfolio rather than holding only one share (Markowitz, 1952). So according to CAPM, the marketplace compensates investors for taking systematic risk, but not for taking unsystematic risk.

As investors should only be compensated for taking systematic risk, CAPM produced a measure for that risk which replaces the Markowitz sigma (σ) figure which was a measure for total risk rather than only the systematic one. This measure is the beta figure ' β '. The CAPM formula is the following:

$$E(R_i) = R_f + [E(R_m) - R_f] \times \beta_i$$

where:

$E(R_i)$ = expected return of stock i

R_f = the risk free rate

$E(R_m)$ = expected market return

β_i = beta figure of stock i

Beta can be calculated as follows: $\beta_i = \frac{Cov(r_i, r_m)}{\sigma_m^2}$, where the $Cov(r_i, r_m)$ is the

covariance of the stock's and the market's returns. Covariance measures the tendency

of these two returns to vary together. The σ_m^2 is the variance of the market's returns.

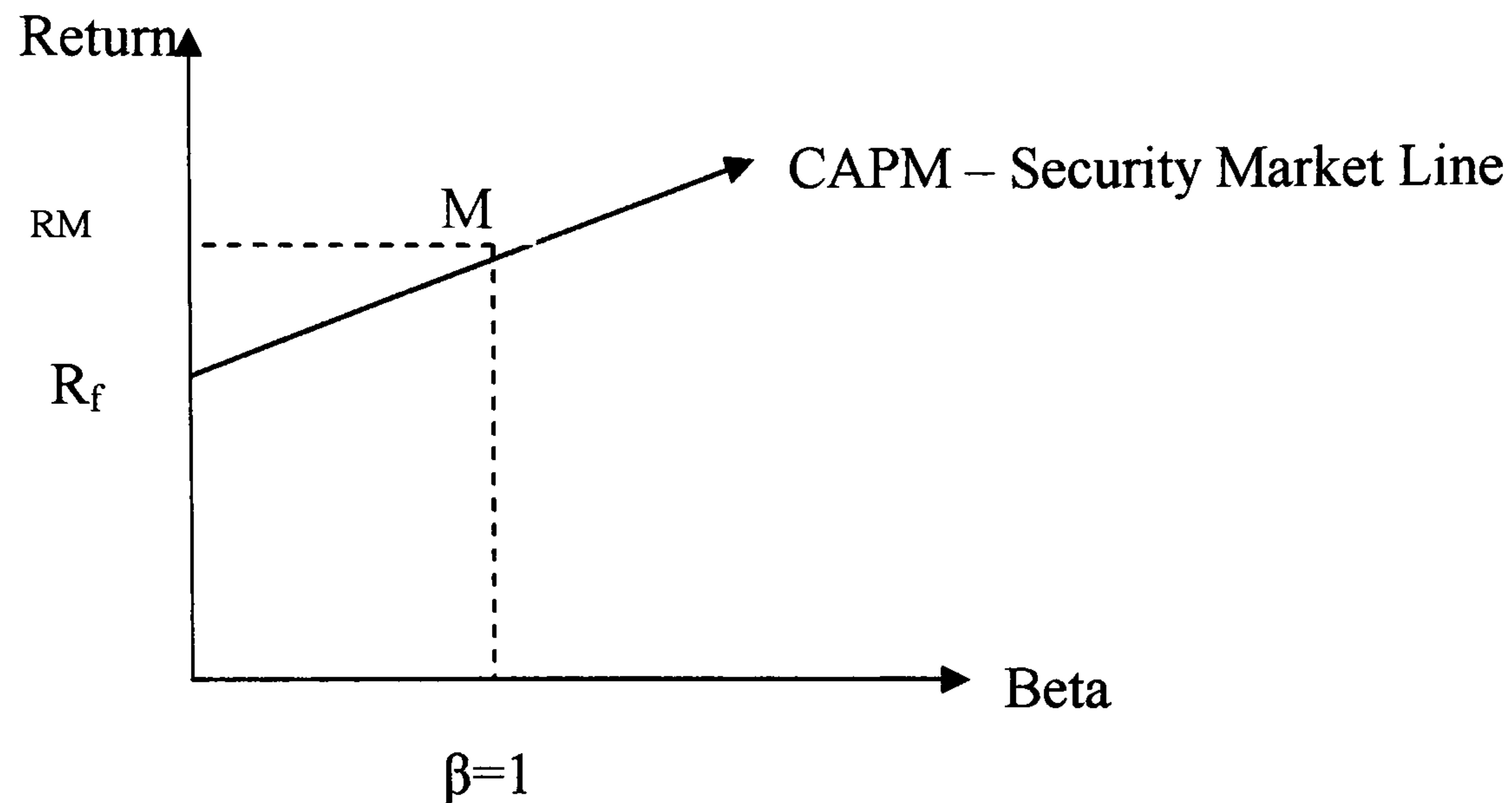
Figure 2.1.: The Security Market Line – CAPM

Figure 2.1 shows the Security Market line, on which M represents the market portfolio i.e. a portfolio that combines all the traded assets. From the CAPM equation, we can see that the risk free rate is a constant and the slope of the Security Market line is:

$$\text{Slope} = \frac{E(R_i) - R_f}{\beta_i}$$

2.3.2. CAPM assumptions and criticisms

Having explained CAPM we should outline the model's assumptions.

Assumptions of CAPM:

1. All assets in the world are traded so every investor can hold the market portfolio.
2. All assets are infinitely divisible so every investor can hold a percentage of the market portfolio.
3. All investors in the world collectively hold all assets in order to create the market portfolio.

4. Investors have homogeneous expectations meaning that they have the same expectations regarding the expected returns and variances.
5. There are no transaction costs so if markets are in equilibrium then there is no arbitrage opportunity.
6. No individual investor can influence the stock price as each investor's funds are only a very small percent of the total funds that are invested in the stock.
7. For every borrower, there is a lender so that every investor is able to either invest more money in the market portfolio or to borrow some money at a risk free rate and make a more defensive portfolio
8. There is a riskless security in the world and all investors borrow and lend at the riskless rate so they can create a more defensive or a more offensive portfolio relative to the market portfolio.
9. There is a one period investment horizon so none of the investors can change their strategy within the investment horizon.
10. Security distributions are normal with a constant mean and variance. Under CAPM, investors would choose to invest in different portfolios only based on the mean (expected return)-variance portfolio selection.

CAPM operates in a perfect world. Yet how perfect is the world in reality? We will not analyse all the assumptions but rather we will concentrate on those that appear to have the greatest weight.

First of all, stock returns may not be normally distributed. In order for stock returns to have a normal distribution, the market must be correctly priced at all times

and thus to exhibit strong-form efficiency. In Chapter 6, we show that there are emerging and inefficient markets and such markets do not have normally distributed stock returns. In fact, we show that the ASE does not have normally distributed returns.

Another major problem with CAPM is the so called market portfolio. The market portfolio is very difficult, if not impossible, to be estimated. This is why many studies use proxies such as the S&P 500 index, which could obviously lead to the misspecification of the model. Similarly, a study by Torz (1998) showed that by running a linear regression in order to estimate beta, the residuals are not random.

Other assumptions that are questionable are the constant risk free rate and the assumption that investors can borrow and lend at the same rate. Everybody knows that in the real world this is not true, as borrowing money costs more than lending money. Furthermore, interest rates are not constant, but fluctuate constantly. A final point concerning interest rates is that the model uses nominal rather than the interest rates.

Finally, CAPM can only be tested using historic data which makes it unable to produce future predictions. If CAPM could produce future predictions then the market would not be efficient and thus the whole model would collapse as one of the model's assumptions is market efficiency.

Due to the underlying assumptions of the CAPM, the model has been widely criticised. Some of these criticisms are presented below.

Fama and French's (1992) study used monthly returns for the period 1963-1990 on the stocks of NYSE, AMEX and NASDAQ. They examined the size and book to market equity and found that the relationship between beta and returns is not significant. So they concluded that the model does not provide an adequate description of average stock returns for the period of the study.

Additionally Cadsby (1992) found that there are anomalies in the risk-return relationship. In his study he used data from 2/1/1963 until 31/12/1985 for daily stock returns on New York Stock Exchange listed stocks. He used two periods of 10 years each. The total amount of stocks was 672 and 874 respectively for the first and the second decade. He showed that risk was rewarded in the early days of the month but not during the rest of the month and later in the week but not early in the week.

Finally Miles and Timmermann (1996) analysed the variation in expected monthly stock returns for a large cross-section of UK companies, by running cross-sectional regressions of the monthly returns. The result was that firms' betas are not significant in explaining cross-sectional variation in stock returns. They concluded that book-market value, and to a lesser extent company size and liquidity, appear to contain more information than CAPM about variations in expected returns.

However, there have been several studies that are in favour of CAPM. Ng's (1991) analysis covered a period from January 1926 through December 1987, consisting of NYSE common stock returns, and employed a multivariate GARCH approach for analyzing the data. He identified a positive relationship between beta and monthly returns. This tends to support the validity of CAPM as a description of the risk-return trade off in capital markets. A final study by Pettengill et al (1995) supported the same conclusions.

One asset pricing model that developed in order to challenge CAPM was the Arbitrage Pricing Theory (APT) (Ross, 1976). The APT specifies returns as a linear function of more than a single factor, compared to the CAPM which specifies returns as a linear function of the systematic risk. APT is based on the law of one price i.e. that the same product must have the same value at any place. The model is as follows:

$$E(R_{it}) = a_i + b_{i1}I_{1t} + b_{i2}I_{2t} + \dots + b_{ij}I_{jt} + e_{it}$$

where a_i is the stock return if factors are not influencing the stock return and $I_{1t}, I_{2t}, \dots, I_{jt}$ are the various factors. The $b_{i1}, b_{i2}, \dots, b_{ij}$ reflect the sensitivity of the stock's return to changes in the various factors. The assumptions of the APT are as follows:

1. For a given level of risk, investors prefer high returns to low returns. For a given level of returns, investors prefer low risk to high risk.
2. Investors can borrow or lend at the risk free rate.
3. There are no transaction costs or restrictions on short-selling.
4. Investors agree on the factors that influence security returns.
5. There are no riskless arbitrage opportunities.

Assumption 5, of course, is the key assumption and is also referred to as the 'law of one price' or the 'no-arbitrage condition'.

The problem that APT faces is that the model does not specify the factors that influence stock returns. A paper by Roll and Ross (1984) argued that the following four significant factors are likely to influence stock returns:

1. Unanticipated changes in inflation.
2. Changes in expected industrial production.
3. Changes in risk premium.
4. Unanticipated changes in the slope of the term structure.

2.4. Conclusion

Through the presentation and analysis of the EMH and CAPM, we are able to understand the meaning of market efficiency and the assumptions upon which one of the most fundamental asset pricing models i.e. the CAPM, is based. Analysing the EMH can enable us in later chapters to test for market efficiency. Efficiency is a major part of finance theory and specifically in financial markets, as all the major asset pricing models assume efficient markets. In addition, the analysis of CAPM and its assumptions will also enable us to analyse the Black and Scholes Option Pricing Model, as its assumptions are essentially the same as those of CAPM.

CHAPTER 3: The Black and Scholes Option Pricing Model

3.1. Introduction

This study concentrates on the Black and Scholes Option Pricing Model (BSOPM) and examines whether it is an appropriate model to be used for option pricing in emerging markets. Furthermore, the study will try to show that call option prices in Greece are influenced to a significant extent by several market anomalies.

In Chapter 6, we test the emerging status of the Athens Stock Exchange and the Athens Derivatives Exchange. Preliminary information presented in Chapter 1 suggests that the ASE and the ADEX are indeed emerging markets. The emerging status of these stock markets could create pricing problems for call options when their prices are based on the BSOPM.

Before conducting the tests that will enable us to draw conclusions as to whether the BSOPM is an appropriate model for emerging markets, it is important to analyse the actual model. In this chapter, we discuss the BSOPM and its assumptions, and then examine several criticisms of the model and its various extensions, including option pricing on assets with stochastic volatility and option pricing with stochastic interest rates. In addition to the BSOPM, there are several other option pricing models that have been introduced (e.g. the Binomial model, and the Monte Carlo approach to option pricing). We start, therefore, with a brief description of these models.

3.2. Option Pricing Models

3.2.1. Binomial Option Pricing Model

The Binomial Option Pricing Model was introduced by Cox et al (1979) and it is the second most common method of pricing option contracts.

The model breaks down the time to expiration into a very large number of time intervals. Having done that, a tree of stock prices is produced from time zero until the option expiration. At each step, the stock price will tend to decrease and increase according to the volatility and the time to expiration. This is a binomial distribution of the stock price, which shows all the possible prices that the stock can take until the expiration of the option contract.

Having estimated the tree of stock prices, we then work backwards, i.e. from expiration to time zero. At each step and for each possible stock price, the option price is calculated using a risk neutral valuation and based on the probabilities that the stock will rise or fall, the risk free rate and the time interval. At the end of each step's calculation, we have a single price which is the option price of the specific contract.

The advantage the Binomial Option Pricing Model has over the BSOPM is that it can price accurately American options as it can take the possibility of an early exercise into consideration at each step. When an early exercise point is found, it is assumed that the option holder would elect to exercise and the option price can be adjusted to equal the intrinsic value at that point. This then flows into the calculations higher up the tree and so on.

However, one disadvantage of the binomial model is that if the number of time intervals becomes very large, then it is very time consuming to calculate the option prices, even with very sophisticated computers.

We should comment here that the Binomial Option Pricing Model and the BSOPM have the same assumption regarding the stock price distribution. Due to that common assumption, the binomial model with infinite steps is equivalent to the BSOPM.

The model may be illustrated as follows:

$$S \begin{cases} S_u & \text{with probability } p \\ S_d & \text{with probability } q, \text{ where } q = 1 - p \end{cases}$$

where S is the stock price and S_u , S_d are the stock prices if the stock price rises or declines respectively.

With just one period, the option price would become:

$$C \begin{cases} C_u = \max[0, S_u - K] & \text{with probability } p \\ C_d = \max[0, S_d - K] & \text{with probability } q, \text{ where } q = 1 - p \end{cases}$$

where C is the option premium, C_u and C_d are the option premiums for premium's rise or decline respectively and K is the strike price of the option.

With n steps, the binomial formula becomes:

$$C = \left[\sum_{j=0}^n \left(\frac{n!}{j!(n-j)!} \right) p^j q^{n-j} \max[0, u^j d^{n-j} S - K] \right] / r^n$$

where r is the risk-free rate, n is the number of changes that occur in the stock price (rise or fall) and j is the number of stock price rises. However if we denote a as the minimum number of increases that the stock prices must have in order for the option to expire at-the-money then the model becomes:

$$\text{for } j < a \quad \max [0, u^j d^{n-j} S - K] = 0$$

$$\text{for } j \geq a \quad \max [0, u^j d^{n-j} S - K] = u^j d^{n-j} S - K$$

So:

$$C = \left[\sum_{j=a}^n \left(\frac{n!}{j!(n-j)!} \right) p^j q^{n-j} \max [u^j d^{n-j} S - K] \right] / r^n$$

If we now split the underlying price and the strike price the model becomes:

$$C = S \left[\sum_{j=a}^n \left(\frac{n!}{j!(n-j)!} \right) p^j q^{n-j} \left(\frac{u^j d^{n-j}}{r^n} \right) \right] - Kr^{-n} \left[\sum_{j=a}^n \left(\frac{n!}{j!(n-j)!} \right) p^j q^{n-j} \right]$$

3.2.2. A Monte Carlo approach to option pricing

The Monte Carlo simulation on option pricing was first introduced by Boyle (1977). A Monte Carlo simulation is actually a random walk simulation. The model has several assumptions regarding option pricing. These assumptions are:

- The stock price follows Brownian motion
- The returns are log-normally distributed
- The interest rate is continuously compounded
- The stock markets are strong form efficient
- There are no transaction costs
- No dividends are paid

The idea is to run the random walk long enough so that it has time to take a tour through most of the distribution. The actual steps for calculating the option price through a Monte Carlo simulation is:

- Obtain historic prices on each stock to estimate annual volatility, σ
- Simulate stock prices up to the maturity date T:

$$S_T = S_0 e^{[(r_f - 0.5\sigma^2)t + \sigma Z \sqrt{t}]}$$

where Z represents the z values of the normal distribution and t is the time to expiration.

Based on the simulated stock price, the calculated option prices are:

$$C = e^{-rt} \text{payoff}$$

where the payoff is:

$$\text{Payoff} = \max\{S_T - K, 0\}$$

3.2.3. Other recent developments in option pricing models

Researchers and academics have focused in recent years on implied tree models and more specifically, on implied binomial and trinomial trees (Dupire, 1994, Derman and Kani, 1994, Rubinstein, 1994a, Jackwerth and Rubinstein, 1996). The binomial tree assumes that the probability of the stock price increasing or decreasing is known. However, as it is not possible to know these two probabilities, we use the implied probability distribution of the underlying asset.

Future stock prices are estimated based on a random walk, where the underlying has a non-constant volatility which depends on time and the stock price.

So the implied binomial tree uses the observable market option prices in order to estimate the implied probability distribution.

3.3. The Black Scholes Option Pricing Model

3.3.1. The model

The main reasons for analysing the BSOPM are the following:

- It is the world's best known option pricing model
- It is used in most of the world's derivatives exchanges
- ADEX uses the model (specifically, ADEX uses a variation of the BSOPM where instead of the spot index prices, they use the future index prices, with the benefit that there is no need to calculate the dividend yield and the interest rates).

According to the model, the cost of a call option will equal the underlying asset's price minus the price of a discount bond that has the same expiration time as the call option and a face value equal to the option's strike price (Black, Scholes 1973).

Based on the above definition of a call option's premium, we can understand that if the option has a long time to expire, the discount bond price will be near to zero and thus the call premium will be almost the price of the underlying asset. However, if the option's life is very short, then the bond price will be near to its face value and so the option's premium will be near to zero (Black, Scholes 1973).

Well before 1973, Sprenkle (1961) produced an option pricing formula that was very close to the BSOPM. Sprenkle's formula was the following:

$$COP = kxN(b_1) - K^*cN(b_2)$$

$$b_1 = \frac{\ln\left(\frac{kx}{c}\right) + \frac{\sigma^2}{2}(t^* - t)}{v\sqrt{(t^* - t)}}$$

$$b_2 = \frac{\ln\left(\frac{kx}{c}\right) - \frac{\sigma^2}{2}(t^* - t)}{v\sqrt{(t^* - t)}}$$

where:

COP = call option price

x = underlying price

c = exercise price

t* = maturity date

σ^2 = stock's return variance

N(b₁), N(b₂) = cumulative normal density function

k, k* = unknown parameters

According to Sprenkle, k is the ratio of the expected value of the stock at expiration to the current stock price and k* is a discount factor that depends on the stock's riskiness. In other words, k is the expected return of the stock. As is easily observed, the major drawback of Sprenkle's model is these two unknown parameters, i.e. k and k*.

Twelve years later Black and Scholes succeeded in excluding the unknown parameters, which had made the previous model vulnerable. The model that Black and Scholes developed was very similar:

$$C = SN(d_1) - Xe^{-rt} N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) - \left(r + \frac{\sigma^2}{2}\right)(t^* - t)}{\sigma\sqrt{(t^* - t)}}$$

$$d_2 = d_1 - \sigma\sqrt{(t^* - t)}$$

where:

S = underlying price

X = strike price

e^{-rt} = discount factor

r = risk-free rate

σ^2 = underlying asset's return variance

t^* = maturity date

$N(d_1)$, $N(d_2)$ = cumulative normal density function

As can be noticed, Black and Scholes managed to exclude the risk factor by replacing it with a discount factor which can be easily calculated and they managed to exclude the expected return of the underlying asset (also unknown), replacing it with the spot underlying price.

However, as a model, it depends on several assumptions that must be satisfied in order for it to perform well. As we shall see, these assumptions are the basis of the main criticisms levelled against the BSOPM.

3.3.2. Stochastic processes of the underlying assets and Ito's Lemma

a. Stochastic Processes

The BSOPM assumes that stock prices follows a generalised Wiener process in continuous time, i.e.

$$dS = \mu S dt + \sigma S dz$$

The generalised Wiener process differs from the Wiener process (dz) as it contains a drift in the equation by including time (t). According to the Wiener process, successive changes in stock prices are independent and $dz = \varepsilon \sqrt{dt}$.

The generalised Wiener process of a stock can be represented by an Ito process, as a stock with instantaneous expected drift rate and variance. Dividing dS by S gives:

$$\frac{dS}{S} = \mu dt + \sigma dz$$

where μdt is the drift rate and σdz is the volatility. This equation shows that the stock returns have an expected rate of return μ plus volatility (σ). Ito's process, derived from the generalised Wiener process, shows the relationship between the price of a derivative variable and the price of the underlying asset. The price of the derivative variable is not only a function of the Wiener process of the underlying asset and time, but also of some other factors which are influenced by time and the derivative

variable. Ito's assumptions are more realistic than Wiener's and the resulting flexibility of the drift and variance rate seem to better reflect the reality.

The BSOPM assumes that stock prices follow a lognormal distribution. So according to the generalised Wiener process the log-changes of the stock would be:

$$d \ln S = \left(\mu - \frac{\sigma^2}{2} \right) dt + \sigma dz$$

According to the above equation, we can claim that log-stock prices follow a normal distribution with

$$\ln S_T : \phi \left[\ln S + \left(\mu - \frac{\sigma^2}{2} \right) (T - t), \sigma \sqrt{T - t} \right].$$

Through the log-normal distribution of the stock prices, we can identify the probability distribution of the rate of returns earned on the stock between time t and T . Let the continuously compounding rate of return be a . Then the stock price S_T can be written as:

$$S_T = S_t e^{a(T-t)} \text{ where } a = \frac{1}{T-t} \ln \left(\frac{S_T}{S_t} \right)$$

By using the above equation of the log-prices distribution we have:

$$\ln \left(\frac{S_T}{S_t} \right) : \phi \left[\left(\mu - \frac{\sigma^2}{2} \right) (T - t), \sigma \sqrt{T - t} \right]$$

Adding this equation to the a equation gives:

$$a: \phi \left[\left(\mu - \frac{\sigma^2}{2} \right), \frac{\sigma}{\sqrt{T-t}} \right]$$

showing that the rates of return are normally distributed.

b. Ito's Lemma

Ito's Lemma is used in stochastic calculus to find the differential of a function with a specific type of stochastic process and the lemma is as follows:

$$df = \frac{\partial f}{\partial W} dX + \left(a \frac{\partial f}{\partial W} + \frac{\beta^2}{2} \frac{\partial^2 f}{\partial W^2} + \frac{\partial f}{\partial t} \right) dt .$$

W is a generalised Wiener process and $dW = a dt + \beta dX$, where a is the drift and β is the diffusion coefficient. Applying Ito's Lemma in finance and specifically in the generalised Wiener process followed by stock prices (shown above), we have:

$$df = \frac{\partial f}{\partial S} dz + \left(a \frac{\partial f}{\partial S} + \frac{1}{2} \sigma^2 S^2 \frac{\partial^2 f}{\partial S^2} + \frac{\partial f}{\partial t} \right) dt$$

by equating $a = \mu S$ and $b = \sigma S$.

The function f can be the value of a call option where $C = f(S, t)$. The first part of the equation is the deterministic component and the second part is the stochastic component. Ito's Lemma applies only to continuous processes.

3.3.3. The Black Scholes Option Pricing Model assumptions

The BSOPM has several assumptions that are summarised below. These assumptions, as we have already explained, make the model potentially vulnerable to criticisms.

The assumptions and their criticisms are as follows:

- The interest rates are known and constant through time.

Interest rates are fluctuating constantly, i.e. they are not constant throughout the life of the option. A simple example that shows that interest rates are not constant is the yield curve where it is not a straight line.

- The underlying price follows a random walk in continuous time with variance rate proportional to the square of the stock price and constant volatility. Thus the distribution of possible stock prices at the end of any finite interval is lognormal.

This assumption could be reasonable. However in order for the underlying asset to have a lognormal distribution it should be correctly priced and efficient.

Unfortunately, in many markets there are jumps in stock prices that are not frequent and thus they distort the log-normality.

- The underlying asset pays no dividend throughout the life of the option.

In addition to the above assumptions, we should mention that when the underlying asset is a stock or an index then the price levels must be adjusted for the dividend yield, as they do pay dividends. The implication of this assumption to the model is that the higher the dividends the lower the call premiums.

- Options are European style.

This assumption was made as European options can be exercised only at expiration. As American options can be exercised any time this implies that there is greater flexibility for the buyer and thus American options have higher premiums.

- There are no transaction costs.

Another strict assumption is that of zero transaction costs. Transaction costs do exist in all markets and they exist due to the pricing anomalies that exist worldwide. Zero transaction costs could exist only in perfect markets where all investors would have exactly the same information, the markets themselves would be very liquid and the trading would be continuous.

- It is possible to borrow any fraction of the price of a security to buy it or to hold it, at the short-term interest rate.

This is another quite strict assumption as we know that a stock or any other financial asset cannot be divisible.

- There are no penalties for short selling.

In order for investors to create delta hedges they must be able to buy or sell stocks against their position in their option contract. In order for investors to do that there should be no restrictions in short selling.

3.3.4. Variations of the BSOPM

From the above arguments, we are able to conclude that the basic BSOPM is a model with many disadvantages. However, since the first BSOPM version, there were many other variations of the model with adjustments for dividends and interest rates.

The first variation concerns the adjustment for dividends where instead of S we include the variable S^{-qt} , where $-qt$ is the dividend yield. The inclusion of the annual dividend yield was an addition by Merton (1973). Also, the model was adjusted for two expiration dates i.e. the calendar expiration dates (365 days) and the trading expiration dates (about 250 days).

$$C = S^{-qt} N(d_1) - Xe^{-rt_2} N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S^{-qt}}{X}\right) + rt_2 + \left(\frac{\sigma^2 t_1}{2}\right)}{\sigma\sqrt{(t_1)}}$$

$$d_2 = d_1 - \sigma\sqrt{(t_1)}$$

where t_1 and t_2 are the times to expiration based on the trading and calendar days respectively.

Finally, in yet another variation of the model, instead of having to discount the spot price with the dividend yield and having to take into consideration the risk free rate, the option price can be calculated by taking the future price of the underlying asset.

$$C = FN(d_1) - Xe^{-rt} N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{F}{X}\right) + \left(\frac{\sigma^2}{2}\right)(t^* - t)}{\sigma\sqrt{(t^* - t)}}$$

$$d_2 = d_1 - \sigma\sqrt{(t^* - t)}$$

where F is the future price of the underlying asset.

In addition to the traditional version of the BSOPM and the revised versions which allow for dividend yield and future prices, there are option pricing models which allow for stochastic volatility, stochastic interest rates, transaction costs etc. These revised models will be discussed in this section.

3.3.4.1. Option pricing with stochastic volatility

Many researchers (Cox et al, 1976, Hull and White, 1987, Kon, 1984, Rubinstein, 1985, Bodurtha and Courtadon, 1984, Heston, 1993b, Jiang and Van Der Sluis, 2000, Madan et al, 1998, Heston and Nandi, 2000) since the appearance of the BSOPM have tried to relax some of the model's assumptions. One of these assumptions is the constant volatility. These researchers have tried to show that stochastic volatility is independent of the stock price and so should be valued independently. In the case where the volatility is truly uncorrelated with the stock price then BSOPM provides wrong estimates for the at-the-money options (overvaluation) and additionally for the deep out-of-the-money and in-the-money options (undervaluation) (Hull and White, 1987). Furthermore if there is positive or negative correlation between the volatility and the stock price then the BSOPM is producing mis-valued options. Specifically out-of-the-money options are undervalued and in-the-money options are overvalued in the case where we have positive correlation. The opposite is taking place if there is a negative correlation between the volatility and the stock price.

Other researchers have also supported the rejection of constant volatility and have provided evidence which supports stochastic volatility (Kon, 1984, Hull and White, 1987). Opposite results were reported in a study by Scott (1987).

More recent studies (Bakshi et al, 1997, Nandi, 1998, Bates, 2000) show that stochastic volatility can generate more realistic volatility skew on S&P index options. They further conclude that option pricing can be better explained with the use of stochastic rather than constant volatility. Lastly, the study by Shu and Zhang (2003) produces similar results i.e. that by using the Heston (1993) option pricing model, less

bias is observed compared to the BSOPM. To illustrate these developments, consider the models developed by Hull and White (1987) and Heston (1993).

Specifically, Hull and White (1987) tried to incorporate stochastic volatility into the BSOPM due to the volatility smiles that the constant volatility assumption caused. Hull and White showed that Black-Scholes volatility should be replaced by a stochastic volatility term, which would be instantaneously uncorrelated with the underlying asset. They argued that the mean variance (\bar{V}) of the stock over some interval of time $[0, T]$ would equal the integral:

$$\bar{V} = \frac{1}{T} \int_0^T \sigma^2(t) dt$$

Heston (1993) derived a closed-form solution for European call options with stochastic volatility. He allowed for arbitrary correlation between the stock returns and volatility, whereas Hull and White assumed that stock returns and volatility were instantaneously uncorrelated. Heston's (1993) volatility would have the following process (an Ornstein-Uhlenbeck process):

$$d\sqrt{v(\tau)} = -\beta\sqrt{v(\tau)}dt + \delta dW_t^2$$

However in a comparative study by Kim and Kim (2004) on option pricing models with stochastic volatility, they argued that Heston's (1993) model outperformed the others.

3.3.4.2. Option pricing with stochastic interest rates

The most important paper that produces a revised BSOPM when interest rates are stochastic was produced by Merton (1973). Merton's addition to the BSOPM was the replacement of the instantaneous interest rate (r) by the stochastic rate of interest $R(t,T)$. Merton argued that the price of the discount bond at time t is $P(t,T) = e^{-R(t,T)(T-t)}$. However Merton also replaced constant volatility by the stochastic volatility:

$$\sigma^2(T-t) = \int_t^T (\sigma^2 + \sigma_p^2 - 2\rho\sigma\sigma_p) dt$$

where the parameter σ is the stock's volatility, σ_p^2 is the variance of $P(t,T)$ and ρ is the correlation between the stock's and bond's prices. So the BSOPM according to Merton is:

$$C = SN(d_1) - P(t,T)XN(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) - \ln P(t,T) + \frac{\sigma^2}{2}(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

A paper by Jiang and Van Der Sluis (2000) also develops an option pricing model with stochastic interest rates as well as stochastic volatility.

3.3.4.3. Option pricing with the incorporation of transaction costs

Leland (1985) developed an option pricing model which could incorporate transaction costs. The main argument is that we cannot ignore transaction costs when we price options as continuous trading and continuous replicating strategies in the presence of transaction costs are extremely costly. Leland's (1985) option pricing model would converge to the BSOPM as transaction costs approach zero.

According to Leland's model, transaction costs are correlated with the change of stock prices and thus to the market and their risk (or uncertainty) becomes larger as the time interval approaches to zero. So Leland (1985) argued that transaction costs affect volatility and thus volatility is influenced not only by the time interval and the stock's variance, but also by transaction costs. Leland defined k as a 'round trip' transaction cost, which is a fraction of transaction volumes. He showed that

$$\hat{\sigma}^2(\sigma^2, k, \Delta t) = \sigma^2 \left[1 + kE \left| \frac{\Delta S}{S} \right| / \sigma^2 \Delta t \right] = \sigma^2 \left[1 + \sqrt{(2/\pi)} k / \sigma \sqrt{\Delta t} \right]$$

where $E|\Delta S/S| = \sqrt{(2/\pi)}\sigma\sqrt{\Delta t}$ and represent the expected change of a stock price, S

The BSOPM then becomes:

$$C = SN(d_1) - Xe^{-r(T-t)}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{Xe^{-r(T-t)}}\right)}{\hat{\sigma}\sqrt{T-t}} + \frac{1}{2}\hat{\sigma}\sqrt{T-t}$$

$$d_2 = d_1 - \hat{\sigma}\sqrt{T-t}$$

3.3.5. Implied volatility problems: Volatility smiles and term structure of volatility

Despite the fact that these variations were developed, there are still pricing problems with the BSOPM. One of the main reasons for such mis-pricing is the implied volatility.

Furthermore, markets are divided into mature and emerging. Mature stock markets are considered to be more efficient due to the participants, the legislation that exists, the controls of the markets etc. However, even mature markets do appear to have anomalies. But one would expect that emerging markets would suffer from even more severe market anomalies. In Chapter 4, several studies are presented and analysed, which investigate the efficiency levels of mature and emerging stock markets and the anomalies that exist. The market anomalies that exist do not allow stock markets to operate efficiently and thus the indexes or stock prices will not be efficiently priced. Additionally, several studies have shown that index and stock prices do not appear to have lognormal distributions but rather show evidence of skewness and kurtosis. Also, insider trading and asymmetric information appear to be prevalent in many markets.

As we mentioned, a major disadvantage of the BSOPM relates to implied volatility. Is implied volatility the correct measure to use? How can a market predict volatility if it is not efficient? These are important problems that arise from the model.

Further questions on the issue of implied volatility were posed by Chance (2003) such as: *“How can the option market tell us that there is more than one volatility for the underlying asset?”* and he replies: *“It does not”*. It can be realised from the above question how important is the implied volatility problem. Chance argues that the BSOPM is incorrect as it provides more than one volatility for an

option with the same underlying asset but different expiration dates and exercise prices. To give an example for the implied volatility problem, think that we know the volatility but not the option price. In that case we would estimate the implied option price from the volatility. However, we would get more than one option price. How can an asset have more than one price at a specific time? We cannot (Chance, 2003).

The case explained above is called implied volatility smiles. Stochastic volatility can actually explain why implied volatility exhibits volatility smiles. It can also explain the term structure of implied volatility. A volatility smile can be observed when we plot a graph of implied volatility against the strike price of the same underlying asset with the same maturity.

Apart from stochastic volatility, which can explain volatility smiles, there are some other explanations as well. One of them could be the BSOPM's assumption about the lognormality of the underlying asset. For example, if prices exhibit leptokurtosis then this could mean that the deep in-the-money options and the deep out-of-the-money options are overpriced compared to the BSOPM theoretical values. In such cases, volatility will also be different (Alexander et al, 2003).

Ederington and Guan (2000) also presented evidence that implied volatility smiles resulted from the BSOPM's assumptions of lognormality and constant volatility. However, they argued that hedging strategies could provide a further explanation. They argued that, since fund managers would hedge their risk with out-of-the-money put options, these strategies would raise the prices of the out-of-the-money put options and consequently their implied volatilities.

Implied volatility also has a term structure. This is another argument against the constant volatility assumed by the BSOPM. The volatility term structure can be observed if we plot a graph of the implied volatility for the same option contract on

the same underlying asset with different maturities. We will observe that despite the fact that the underlying asset is the same, volatility changes according to the expiration period.

As we have already mentioned, due to the volatility term structure and smiles, many option pricing models were created which tried to incorporate changes in volatility. These models can be categorized into stochastic volatility models, where these models allow the underlying asset to be leptokurtic and into local volatility models such as the implied binomial tree models, where these models assume that volatility is deterministic and depends on time and on the underlying asset.

A general conclusion that can be drawn from the above analysis is that the BSOPM, despite the development of several variations, still has problems due to the assumption of log-normality, due to the exclusion of transaction costs and due to other market anomalies. This study will try to show that market anomalies exist and discuss whether these anomalies and transaction costs have a significant effect on option pricing.

In the next section we will discuss the various methods for calculating the implied volatility.

3.3.6. Calculation methods for implied volatility.

The implied volatility measure which is used by the BSOPM can be calculated in more than one way. The most common way to calculate implied volatility is to solve the Black-Scholes equation for σ . An approximation of the implied volatility that is derived from the BSOPM is the following (Corrado and Jordan, 2002):

$$\sigma \approx \frac{\sqrt{2\pi/t}}{Se^{-yt} + X} \left(C - \frac{Se^{-yt} - X}{2} + \sqrt{\left(C - \frac{Se^{-yt} - X}{2} \right)^2 - \frac{(Se^{-yt} - X)^2}{\pi}} \right)$$

where Se^{-yt} = spot index prices discounted by the dividend yield. However as we can see this method offers only an approximation of implied volatility. In addition to the above formula, there are several other ways by which one can calculate implied volatility.

a. Newton–Raphson Method

The Newton–Raphson method forecasts implied volatility according to the market value of the call option and according to the vega value of that option. The formula is as follows:

$$\sigma_{i+1} = \sigma_i - \frac{c(\sigma_i) - c_m}{\partial c / \partial \sigma_i},$$

where, σ_{i+1} = the implied volatility at i+1

σ_i = the implied volatility at i

c_m = the market premium of the call option

$\partial c / \partial \sigma_i$ = the vega figure of the call option

This method requires iterations (usually a maximum of 3) until it converges on the implied volatility, i.e. until $|c_m - c(\sigma_{i+1})| \leq \varepsilon$, where ε is the required accuracy level.

Based on the Newton–Raphson method, Manaster and Koehler (1982) developed a formula that converges to the implied volatility, which was simpler than the Newton-Raphson method. The formula is

$$\sigma = \sqrt{\left[\left| \ln(S/X) + r(T-t) \right| \frac{2}{T-t} \right]}$$

b. Bisection Method

The bisection method has an important advantage over the Newton–Raphson method. In the bisection method, we do not need to estimate vega, which may be unknown. The method takes extreme values for implied volatility, a low estimate (σ_L) and a high estimate (σ_H). The low estimate corresponds to an option premium c_L and the high estimate to an option premium c_H . The market price of the option will fall between the high and the low estimate i.e. $c_L < c_m < c_H$. The formula that this method uses is:

$$\sigma_{i+1} = \sigma_L + (c_m - c_L) \frac{\sigma_H - \sigma_L}{c_H - c_L}.$$

The final step is to replace σ_L with σ_{i+1} if $c(\sigma_{i+1}) < c_m$ or to replace σ_H with σ_{i+1} if $c(\sigma_{i+1}) > c_m$, until $|c_m - c(\sigma_{i+1})| \leq \varepsilon$.

c. Other Approximations

In addition to the Newton–Raphson and bisection methods, there are other implied volatility approximations such as the at-the-money forward approximation by Brenner and Subrahmanyam (1988) and Feinstein (1988) and the extended moneyness approximation by Corrado and Miller (1996a).

The at-the-money forward approximation is:

$$\sigma \approx \frac{c_m \sqrt{2\pi}}{S e^{(b-r)T} \sqrt{T-t}}$$

where c_m = the market premium of the call option and the at-the-money forward is

$$S = X e^{-b(T-t)}.$$

The extended moneyness approximation for call options is:

$$\sigma \approx \frac{\sqrt{2\pi}}{S e^{(b-r)(T-t)} + X e^{-r(T-t)}} \left\{ c_m - \frac{S e^{(b-r)(T-t)} - X e^{-r(T-t)}}{2} \right. \\ \left. + \sqrt{\left[\left(c_m - \frac{S e^{(b-r)(T-t)} - X e^{-r(T-t)}}{2} \right)^2 - \frac{(S e^{(b-r)(T-t)} - X e^{-r(T-t)})^2}{\pi} \right]} \right\} / \sqrt{T-t}$$

3.3.7. Criticisms of the Black and Scholes Option Pricing Model

There are many critics of option pricing models and most of them have directed their criticisms at the BSOPM. Some authors have identified bias in option pricing through the BSOPM as the model is based the assumption that the stock's/index's return volatility is constant, which in most real-world situations is not the case (Bystrom, 2000, Bates, 1995).

Additionally, a single arbitrage-based model cannot fully incorporate the implied volatility's patterns, which mean that it is unable to price the option at a fair value. Yet the stochastic volatility models or preference-based models have the ability to follow these patterns, yet they do not fully incorporate them (Sheikh, 1991). At the same point, Sundaresan (2000), points out that the use of implied volatility from the BSOPM produces the volatility smile and skew. He identified that the smile or skew have term structure. They seem to be stronger for short-term options and less strong in options with long-term to expiration.

Hull and White (1987) tested the option pricing on assets with stochastic volatility. The exchange under examination was the CBOE for the period 1976-1978. The instrument that was used to perform the tests was the 30 most active options. Their results in short are as follows. If there is a positive correlation between stock prices and volatility, then the out-of-the-money options are underpriced by the BSOPM, and the in-the-money options are overpriced by the same formula. When we have a negative correlation, then the opposite happens i.e. the out-of-the-money options are overpriced and the in-the-money options are underpriced. Other studies related to stochastic volatility are discussed in Section 3.2.3.

Long and Officer (1997) studied the BSOPM in relation to the volume of transactions. Their data were from January 1, 1983 until December 31, 1985 and the asset under examination was the stock options traded at the CBOE. They identified that the lower the transaction volume, the higher the option's mispricing, i.e. the higher the pricing inefficiency. Yet an interesting point is that they argued that even with very high traded options, mispricing errors still occur. Only an average number of trades would make the BSOPM efficient. However, heavily traded options could be

an indication of new information arrival and so the pricing inefficiency would be only temporary.

Chance (2003) argued that the BSOPM is incorrect not only due to the implied volatility problem that was mentioned above. Another major reason for arguing that the BSOPM is not a correct model is that it is a partial equilibrium model rather than a general equilibrium model. General equilibrium models provide explanations based on the demand for and supply of assets. BSOPM does not refer anywhere to the demand for and supply of options, how many options investors should hold in their portfolios, or why an investor would choose to buy an option instead of performing another strategy.

Furthermore, according to Jackwerth and Rubinstein (1996), the BSOPM exhibits bias in the at-the-money option prices. Two reasons can explain such bias. The first one is that the implied volatility of the at-the-money option rarely equals the historic volatility. The second reason is the one we have mentioned before, i.e. the different implied volatilities for the same underlying asset in options with different strike prices and expiration dates (Chance, 2003, Rubinstein, 1994, Jackwerth and Rubinstein, 1996).

3.4. Conclusion

We have seen in this chapter that the BSOPM has several disadvantages, which make it a vulnerable model. First, the model has very strict assumptions that are unlikely to hold in the real world. Second, the model has a serious problem with implied volatility and the consequences that this measure brings to the model.

In the next chapter, the main literature review is presented. This includes a review of empirical studies concerned with stock and derivatives markets in emerging economies, the interrelationship between stock and option markets and efficiency testing in stock and option markets.

CHAPTER 4: Empirical Studies on Options and Stock Markets

4.1. Introduction

The subject of this thesis is the behaviour and the pricing of options in emerging markets. The literature review below first discusses emerging markets, their main characteristics and features, and the behaviour of the stocks and the traders operating in these markets. It then identifies and explains the anomalies of the stock markets, which will help us in our analysis of the derivative exchanges.

Market anomalies, also called inefficiencies, are more accentuated in emerging markets than in mature markets. Smart traders can take advantage of these anomalies and generate abnormal profits, causing losses to noise traders. This is an important consequence not only for the going concern of the markets, but also for the efficiency of the derivative markets, as these are affected by their underlying markets (i.e. the stock and capital markets).

4.2. Empirical studies on stock and derivative markets

4.2.1. Emerging markets and their inefficiencies

When describing emerging markets, ‘country effects’ are considered to be the most important factor driving the behaviour of stock returns and their indices (Serra,

2000). Country effects also create high correlation between the listed stocks because of the correlated fundamentals (Morck et al. 2000, Serra, 2000, Roll, 1992). High correlation of listed stocks is also explained by the political situation surrounding emerging markets, where an event can cause the rise or fall of the whole market, rather than that of specific sectors. Because ‘common effects’ play a less important role in emerging than in mature markets, it seems that emerging markets are affected by fewer pricing factors, or that these factors are priced differently (Serra, 2000). Also, emerging markets tend to be more volatile than mature markets. This creates opportunities for institutional and non-institutional investors who take advantage of the volatility variance. Derivative markets in emerging economies are less liquid, because most of the investors, domestic or foreigners, are reluctant to write calls (Alexander, 1999).

The efficient markets hypothesis assumes information efficiency, and borrowing and lending at the same interest rate (see CAPM and EMH, French, 1989). These assumptions do not apply in real markets, and many researchers have noticed several market anomalies such as the January effect, the weekend effect, the small firm effect, etc. (Cuthbertson, 1997). These effects distort markets, as they tend to make them predictable.

Some authors propose the view that trading strategies based on investment concepts could lead to the prediction of stock movements (Lander et al, 1997). Keim and Strambaugh (1996) argued that the financial and accounting elements of firms listed in stock exchanges affect returns by their predictability power. Hodrick (1992), Lamont (1998), Harvey (1995) and Richards (1996) found evidence of mean-reverting

components in equity and foreign exchange markets. Overall, predictability has an important effect on markets as it can yield abnormal profits to investors. But it is inconsistent with the efficient markets hypothesis (EMH, Fama, 1991). However, other studies conclude that there is no evidence of market anomalies or signs of predictability ((Bidarkota and McCulloch, 1996), Cooper et al (1998), Ghysels et al (1996)).

Emerging markets also tend to be characterized by investors' behaviour. Chang et al (2000) found that emerging markets, such as the South Korean and Taiwanese, exhibited investor herding behaviour. They also identified herding behaviour in the Japanese market, despite the fact that it is a mature market. However, they did not find evidence of herding behaviour in traditional mature markets, such as the American market, nor did they find evidence in the Hong Kong market, despite its emerging profile.

Emerging markets also include noise traders. These traders, characterized by their systematic mistakes, overemphasize the importance of past prices in their analysis and investment decisions and overreact to any new information reaching the market. Theoretically, 'smart money' investors should cause noise traders to disappear after a short period of time. Yet, if these traders are continuously entering the market, then they will provoke market distortions, as mentioned above (Shleifer and Summers, 1990, Shiller, 1989). The results of the study of Hayo and Kutan (2001) go in the same direction: they tested stock returns in six countries (Indonesia, South Korea, Argentina, Brazil, Pakistan and Russia) for the period 1997-99 and discovered that investors tend

to overreact to bad information. They characterized this as investor panic, which causes significant drops in the stock markets.

Every stock market carries a specific level of risk which, according to Poterba and Summers (1988), is an important determinant of stock prices. The authors demonstrated that it is the perceived risk that affects stock prices, not the actual risk. Hence, if a high risk perception holds for a long period, then the effect on the market in future periods is significant. This can be problematic for emerging markets, as they present a higher level of risk compared to mature markets and are perceived as such. Market crises tend to hold longer in emerging markets, as well as the time needed for recovery (Patel and Sarkar, 1998, Seyhun, 1990). The combination of these three elements, higher level of actual risk, perception of higher risk by investors, and more intense market crises, demonstrates how dangerous emerging markets can be. It is worth noting that none of these elements is included in option pricing models.

The 'jump' condition (Merton, 1975) is also a determinant of stock prices and has an indirect effect on option prices. The more 'jumps' a stock price exhibits, the more valuable is the option on this stock. In an emerging market, where stock price jumps are more frequent than in mature markets, options should have higher values.

The efficiency level of emerging markets has been the subject of many researches. Cornelis (1998) studied six Asian stock exchanges and discovered that only information from past prices reached these markets, a contradiction to EMH. Furthermore, for markets to be efficient, they have to be able to guide capital towards its best economic use (Morck et al, 2000). The fact that emerging markets are less

effective processors of economic information than the mature stock markets characterizes them as less efficient.

In order to test the efficiency level of emerging markets, a researcher can analyze stock price movements on the day before and after the liberalization day (Morck et al, 2000). Bekeart and Harvey (1998), Buckberg (1995), Kawakatsu and Morey (1998), and Kim and Singal (1997) have researched this topic, but their results are inconclusive because of problems related to the identification of the liberalization day, or the fact that liberalization can take a whole period in order to be finalized. Basu and Morey (2000) demonstrated that liberalization provides greater efficiency to emerging markets. In their study, they found that stock prices in emerging markets follow a random walk after markets have been liberalized.

Henry (2000) tested the same issue and concluded that liberalization has a very positive influence in emerging markets as it can increase market valuation by 20%. An important point from this study is that Henry distinguished financial reform from economic reform, and found that both play the same role regarding market revaluation.

Because emerging markets tend to be less liberalized, they have difficulties in attracting foreign investors, and therefore have limited funds. Moreover, foreign investors are a major component in the growth of emerging markets. Foreign institutional investors usually place their funds in secure markets. Their decisions affect the investment decisions of local investors, i.e. they become more involved in stock markets. The larger the number of investors in a market, the greater its growth and maturity.

In addition, Wheeler et al (2002) performed a study of the Warsaw Stock Exchange (WSE) during the period 1991 to 1996. The study analysed the efficiency level of the WSE during the transition period of the Polish economy by using a runs test and an autocorrelation test on the stock price returns. They argued that the market overall was not efficient yet there was an improvement of the efficiency level as the trading session increased.

Summarizing, emerging markets have several characteristics that distinguish them from mature markets. Emerging markets tend to be driven by market rather than by firm or industry factors. Consequently, they present synchronous stock movements, with less diversification opportunities (Haugen, 1997). Additionally, seasonal effects on stock prices are predictable in emerging markets, which makes option valuation more difficult. These markets tend to include more noise than rational traders, a situation yielding negative consequences for stock valuations.

According to studies, stock returns have presented signs of predictability in emerging markets. This is problematic for option valuations, as option pricing models do not include a predictability element. Also, traders, in order to generate abnormal returns, can use predictability and write or sell contracts to their benefit, distorting the market behaviour. Incomplete markets are more volatile than complete markets. This volatility, a measure of risk, can diminish market attractiveness.

As Richards (1998) points out, emerging markets due to their unique characteristics, differ from mature markets. Their differences can be summarized as high liquidity risk, limited number of assets available and low market capitalization. According to other researchers, emerging markets tend to have high political risk

because of political instability, and economic risk because of currency devaluations, financial shocks, etc. (Bekeart et al, 1997, Erb et al, 1997).

We will now concentrate on the analysis of several market anomalies that can distort option prices but according to Heston (1993), are not included in option pricing models.

4.2.2. The importance of option markets in emerging markets

Kilcollin and Frankel (1993) described the important role of option markets in Eastern Europe, which is characterized by a large number of emerging markets. According to the authors, their advantages are the greater liquidity and depth of the markets, and, to a greater extent, the price stability caused by the hedging, speculating and arbitrage opportunities created, as well as, thanks to the clearing house, the elimination of the credit risk associated with various transactions. But these markets also present problems related to the difficulty of understanding their operating mode, to the regulations that inhibit foreign investors from entering these markets, to the higher cost for an outsider to enter and gain knowledge of these markets, and/or to the greater risk faced by firms or investors in Eastern European markets because of political instability, and currency instability. This situation causes fewer investors to enter the derivative markets.

Most, if not all East European markets are emerging. We can therefore assume that the important role of the derivative markets for these countries can be extended to all emerging markets.

4.2.3. Interrelation between option and stock markets

The interrelation between option and stock markets is an important issue, often examined from different angles. Some authors examine the relationship between the markets in general terms i.e. whether options provide efficiency to stock markets, or whether there is general interaction between both markets. Other authors study the option listing effects on individual stocks or on overall markets. Finally, others research which of the two markets is the primary market for investors, the one in which investors trade first. This distinction helps academics and practitioners to understand which market bears information to the other. We will examine these three different approaches in the following sections.

4.2.3.1. Relationship between stock markets and option markets

Many researchers have conducted studies regarding the interrelation between option and stock markets, producing different results.

Chan et al (2002) analyzed the interdependence of shares and their listed options in NYSE and CBOE. They observed that stock returns lead option returns. This indicates that order flows in stock markets are informative, that order flows in option markets are not, and that informed traders trade first in the stock market and then in the option market.

Other studies, by Stephan and Whaley (1990), and Boyle et al (1999), support the view that the stock market leads the option market. The minimum price that an

option premium and a stock price can change is called tick size. For the US, market tick size for a stock is 1/8. Consequently, a small move of a stock is not reflected in the option price. Because a large stock movement (up or down) is required for an option price to change, we can consider that options do not reflect all the movements of stocks. Based on that concept, Chan et al (1993) observed that the stock market leads the option market by 15 minutes. They used for their study a non-linear multivariate regression model, with the change of the call prices as the dependent variable. The independent variables were the change in stock price and the delta value. They examined stock and option prices for the 1st quarter of 1986 from NYSE, American Stock Exchange and CBOE. They explain this lead by the way the options and stock are traded. But, if the test performed had been examined with the bid-ask spread instead of the transaction costs, then this lead would disappear. Stephan and Whaley (1990) presented the same conclusion.

Boyle et al (1999) studied the relation from a different point of view. One of their findings was that if the stock market leads the option market, as they had found, then the implied volatility may be biased depending on the level of true volatility i.e. the higher the true volatility, the more upward bias there is in the implied volatility.

On the other side, Manaster and Rendleman (1982) performed an ex-post and ex-ante test that contained closing stock and option prices to form portfolios in order to test whether there is more information in either the stock prices or the option prices. The tests were conducted under the assumption that the trader can simultaneously process the information and trade at the closing stock prices. The trader can use future information because he can trade at closing option prices. The ex post test had a

difference as it has an extra assumption i.e. that the stock purchase could take place at the closing price of the next day. They concluded that the closing option prices contain information regarding the underlying stock that is not incorporated in the underlying price for up to 24 hours. In this case, the option market leads the stock market. This could enable investors to earn excess return if the information contained in the closing option prices are interpreted properly. This would be a sign of inefficiency and contradict the efficiency model. Similar conclusions can be found in a study by Grenadier (1999)

Other studies by Bhattacharya (1987), Anthony (1988) and Easley et al (1998) also concluded that option markets lead stock markets because they presented information, which predicts future stock price movements. Easley et al (1998) developed their own model of multimarket trading. It is a sequential trade model in which the traders make transactions in option and stock markets with risk neutral and competitive market makers. Their study contains 44 trading days from October to November 1990. The sample consisted of the first 50 firms ranked according to daily trading volume in the Market Statistics report of the CBOE. They suggested that only certain types of option trades have some predictive power for future stock price changes.

Kumar and Shastri (1990), who analyzed the study of Manaster and Rendleman (1982), found that traded options do not include information on the underlying asset. The period of their study was from 22/8/77 until 31/8/78. The data were all the traded options from the CBOE, including their maturity periods and transaction prices. Finally, Vijh (1990) concluded that the price effect of large option trades is generally

small, suggesting that option trades do not include information, but the study presented no indication of whether the stock or the option market leads the other.

Although an abundant literature, there is no clear evidence on which market leads the other. This issue is important. If the option market leads the stock market, then it is positive for the market because options, as described earlier, provide greater efficiency to the underlying market. But, if options have predictable power regarding stock movements, then the option market supplements the underlying market.

However, if the stock leads the option market, then this could create several problems to the rational operation of the option markets. This can be justified by the evidence of inefficiencies that emerging markets present. If these inefficiencies are incorporated in the option market, then options cannot be priced at a fair value and arbitrage opportunities may be created.

4.2.3.2. Predictability of option markets

Easley et al (1998) used data from the CBOE on every traded option. The information included the time to expiration, expiration month, strike price and bid-ask prices. The period of the study was from October until November 1990. They suggested that the larger transactions in the option market would be a predictor of future movements in the underlying price. This was justified by the argument that informed traders would choose to trade more heavily in the option market, this market reflecting the information first, and then this information would be incorporated in the underlying prices. So they concluded that information asymmetry combined with

higher trading activity of an option could predict future movements of the underlying price. However, researches by Manaster and Rendleman (1982), Detemple and Jorion (1990), Stephan and Whaley (1990), Stoll and Whaley (1990), Sheikh and Ronn (1994), Mayhew et al (1995), and Fleming et al (1996) could not present conclusions regarding which market reflects information first.

Lo and Wang (1995) produced a different study. They tried to investigate whether underlying price predictability could affect option prices. They concluded that underlying price predictability has an impact on option prices even though it is not included in any option price models. The impact is indirect, through volatility, a component of option pricing formulas. This means that volatility can be biased when there is evidence of predictability for future share price movements. In that case, volatility is not estimated correctly and the level of bias is a function of the level of predictability.

4.2.3.3. Overreaction, mis-reaction, and under reaction of options

Another important element is the identification and the analysis of the over-reaction, mis-reaction, and under-reaction that can be identified in option behaviour in relation to stock movements.

For Bakshi et al (2000), call (put) option prices were decreasing (increasing) even when the stock price was dropping. In order to come to this conclusion they used all intraday observations on the S&P 500 spot index, lead-month S&P 500 future prices and bid-ask midpoint prices for the S&P 500 index options, from 1st of March

1994 until 31st of August 1994. They actually tested whether option prices violate the following conditions. First that as stock price increases then call options should have a positive change and put options a negative change and secondly whether call and put options with the exact same characteristics have equal changes, yet with different sign. David and Varonesi (1999) concluded that in bull periods, in-the-money options move in the same direction as stock prices with higher drift, and out-of-the-money options move in the opposite direction. During bear periods, the situation is the opposite.

Potesman (2001), in a similar study, concluded that “investors under-react to information contained in daily changes in instantaneous variance, investors over-react to long periods of mostly similar information in daily changes in instantaneous variance, and investors misreaction, to the information contained in daily changes instantaneous variance, is increasing in the quantity of previous similar changes in instantaneous variance” (p.874).

Diz and Finucane (1993) presented the opposite conclusion. Testing S&P 100 (OEX) using a mean reverting process, they did not observe any overreaction in index options. Their study was based on Stein’s (1987) findings which implied that volatilities of long-term S&P 100 index options overreact to changes in short-term volatilities.

These option under-, over-, or mis-reactions to stock movements can be a problem for emerging markets, as they represent irrational stock price movements. Overall, this situation may lead to mis-pricing of options.

4.2.4. Effect of option listing on the underlying stock and the market

According to researchers, the effects that the option market introduces to the stock market are both positive and negative. These effects are mostly concerned with the variance of stock returns and volatility.

Stein (1987) suggested that option listing affects positively and negatively the stock variance because of the presence of two kinds of investors i.e. hedgers and speculators. The first group reduces the variance and the second group, due to their potential ability to reduce information flows, increases the variance.

Most studies suggest that option introduction results in the reduction of stock variance (Skinner, 1989, Conrad, 1989, Bansal et al. 1989, Klemkosky, 1978, Jenings and Starks, 1986, Damodaran and Lim, 1991, Nabar and Park, 1988, Mayhew and Mihov, 2000). Yet, in a perfect market, the introduction of options should have no effect. This is also supported by the study conducted by Grossman (1989) who demonstrated that due to the existence of incomplete markets and transaction costs, the listing of options could affect stock variances.

According to Kumar et al (1995), the introduction of options in the US market decreases market volatility and increases liquidity. These authors also concluded that the trading volume, volatility and bid-ask spread declined for stock in the Nikkei 225 index after the listing of index options. They used event studies to produce their results. Their sample consisted of all the stocks listed in the First Section of the TSE (Tokyo Stock Exchange). They also found that trading volume ended to increase in the US markets after the option listing.

The effects presented above seem to have greater impact in the early days of the option introduction, because of arbitrage and hedging opportunities. Detemple and Jorion (1990) came to this conclusion after conducting an event study in which they developed a pre-event window to estimate the parameters of the expected returns models starting 60 days and ending 7 days before the event date. A non-parametric test was used to detect changes in stock return variances after the option listing.

The option expiration date also affects stock variance and transaction volume (Pope and Yadav, 1992). Their data contained option expiration dates for the period October 1982 to September 1987, which resulted in 465 events at the individual firm level. Option expiration seems to be accompanied by higher transaction volume, but there is evidence that during the post-expiration period there is an immediate drop in transaction volume. Volatility does not appear to be subject to significant changes because of option expiration.

Freund et al (1994) suggested that the introduction of options has less effect on stock variance than is generally believed. Additionally, the authors did not find evidence that the introduction of an option would destabilize a stock.

Some researchers disagree with the opinion that the option introduction has as main effect reduction of stock variance and volatility. Long et al (1994), Lamoureux (1991), and Bollen (1998) found no evidence of an effect on the stock variance. The latter author used a large data set to support his result.

Trillo (1999) argued that, in the Mexican Stock Exchange, the introduction of a derivative market without a clearing house did not have a favourable effect on the volatility of the underlying stocks. To perform this test, he developed a proxy for daily

stock variance through the GARCH model. More precisely, he first generated a time-series measure of stock return volatility through ARCH and GARCH processes. Then he used a dummy after the introduction to determine the impact of the derivatives introduction in the stock return volatility. The final sample was 178 observations issued on 33 stocks and the Mexican market index.

According to Skinner (1989), Black (1975), Stephan and Waley (1990), Fleming et al (1996) and Fedenia and Grammatikos (1992), there are three possible reasons to explain why option listing affects stock variance. The first is the criterion of choice for stocks to list options. Specialists choose a stock to list an option if its variance of return is unusually high or is increasing. Yet if the variance is mean reverting, then this means that it is likely to return to the normal level after the introduction of the option. The second explanation is that option markets attract informed traders as these markets are considered more efficient. Finally, the bid-ask spreads in the stock market can be decreased by the introduction of options, so it reduces the variance of stock return.

4.2.5. Option markets are efficiency providers

Another way in which the option market may affect the stock market is by providing greater efficiency to the underlying asset.

According to Amin and Lee (1997), the opening of an option market provides greater price efficiency to the stock market. Firms that have listed options tend to adjust their stock prices to various events faster (Jennings and Starks, 1986). Skinner

(1990) and Ho (1993) supported the view that the option market provides greater efficiency to the stock market, as market reactions to earning announcements are smaller. Furthermore, Botosan and Skinner (1993) concluded that stocks with listed options have less predictable drifts after announcements.

Detemple and Selden (1986) found that option listing leads to asset price increases and generally that financial innovation which takes place in incomplete markets provides opportunities for higher returns.

Ma and Rao (1988) suggested that the impact of option listing is positive for stocks that experience high volatility because options, by providing hedging opportunities for uninformed traders, make stocks more stable. Option listing has the opposite effect for stable stocks, because options provide speculative opportunities for informed traders, making stocks more volatile.

However, Mendenhall and Fehrs (1999) found that there is a lower response to earning announcements for stocks with listed options, and that this does not last. They used data from the CBOE and for all the traded options. The study was performed for the period 1973-93 and the method of study was a cross-sectional test between firm announcements, listed options and stock prices. They also found that the response to the earnings announcements falls over time, for stocks with and without listed options. Finally, after testing the changes in firms' size and market conditions, they concluded that stock responses increase rather than fall.

However, most of the literature presented above, concludes that options help to complete primary markets and improve their efficiency levels.

Concluding this issue, we can say that there is an interrelation between stock and option market, and that each market complements the other. The introduction of the option market provides efficiency to the underlying market. But the option market depends, for efficient operation, on the underlying market. Inefficiencies observed in the stock market or in individual stocks with listed options create option pricing problems and eventually abnormal reactions.

4.2.6. Efficiency testing in the option market and seasonalities

Testing option market efficiency and seasonalities is important for two reasons: first to understand if there are market anomalies created by stock markets and second to identify these anomalies their implications.

4.2.6.1. Efficiency testing in the option market

There are several studies concerned with the efficiency level of option markets. Veld and Wei (1998) tested the efficiency of Dutch long-term call options through the use of delta, delta-gamma and delta-vega trading strategies. They conducted their test using the delta-vega and the delta-gamma neutral hedges with data from Dutch long-term call options from 1st April – 30th September for the years 1990 and 1991. They concluded that these strategies can offer profits from arbitrage opportunities for ex-post strategies without transaction costs. But, if transaction costs are included, arbitrage opportunities disappear. This suggests that the Dutch long-term call option market is

efficient. It is worth to note that the persistence of delta-vega and delta-gamma strategies needs to be further examined.

Many researchers have tested market efficiency in the option markets. The main ones are: Kemma (1989); Tan and Dickinson (1990) who tested the European Options Exchange (EOE); Chance (1987); Blomeyer and Klemkosky (1983) who tested the CBOE; Kerruish (1984); and Gemmill and Dickins (1986), who tested the London Traded Options Market. Their findings are overall the same, stating that these markets seem efficient as far as abnormal returns are concerned if transactions costs are incorporated in the trades. Tan and Dickinson (1990), who tested the EOE, concluded that no trader can earn more than average after the incorporation of transaction costs in trade. These results support their hypothesis, i.e. that the market seems to be efficient and that efficiency holds over time.

Harvey and Whaley (1992) used the Black Scholes partial differential equation framework. The data used was from the S&P 100 index option contract trading volume from March 1983 until December 1989. They argued that the option prices should be determined by investors' expectations regarding future variance of stocks. Expectation is based on true information held by investors regarding volatility of stocks. In order to test market efficiency, the authors argued that future volatility should be predictable because of information that investors hold, and not as unpredictable as other researchers argue. But predictability of future volatility might create arbitrage opportunities or abnormal profits. Harvey and Whaley (1992), by testing their hypothesis on the S&P 100 Index Option Market, found that the market volatility is predictable statistically, but if transaction costs are included in the model, then

arbitrage opportunities disappear. Therefore, these results indicate that the specific market seems to be efficient.

Gemmill (1992), when testing the efficiency of the London option market, tried to analyze whether stock and option prices are consistent with the final results of 1987 UK general election, as well as with the exit poll prior to the election. He built a probability model which contained variables like the FTSE index, the FTSE index contingent on a Conservative or Labour win, and the probability of a party winning prior the election. The results were that the share prices were consistent with the probability that the Conservatives would win the election, while option prices were not. The interpretation of these results was that option prices were not information efficient, while share prices were.

As stated earlier, testing option market efficiency is important because it gives an indication of whether anomalies observed in option markets are the consequences of underlying market inefficiencies or the consequences of option markets themselves. Based on the literature presented above, option markets seem to be efficient, as tests on many option markets (including the CBOE, LIFFE and LTOM) demonstrate.

4.2.6.2. Intraday, intraweek concepts and seasonalities

There are many markets anomalies, such as the Monday effect (Phillips-Patrick and Scheeweis, 1988), the clearing procedures in the weekend effect context (Jaffe and Westerfield, 1985b), the observation that futures contracts of the Major Market Index rise until 1:30 p.m. on Fridays, then decrease until they complete their fall in the first

30 minutes on Mondays (Finnerty and Park, 1988). Furthermore Harris (1986) argued that the larger firms complete their decline during the first 45 minutes on Mondays, while the smaller firms might continue to fall during the whole trading day. These anomalies affect option markets because they influence the pricing process. Morse (1991) found that implied volatilities increase on Thursdays and decrease on Fridays, only to increase again on Mondays. More specifically, Morse discovered that the difference between the call implied volatility and the put implied volatility decreases on Fridays and increases on Mondays.

Other studies on the same subject produced other important conclusions. Sheik and Ronn (1994) examined the daily intraday behaviour of option returns in the CBOE. They used data for the period 1/1/86 – 30/9/87 and they used all the bid-ask quotes. They concluded that the daily stock returns were similar to those of the adjusted option returns. The same observation appeared for the intraday behaviour. Both adjusted option returns and mean stock returns exhibit a U-shaped pattern during the day. But some patterns were observed for the intraday and daily behaviour on adjusted put returns that were not observed for the adjusted call returns and vice-versa. An example of such an observation was that the adjusted put returns were not significantly positive on Fridays and negative on weekends, a pattern not followed by the adjusted call option returns.

Aggarwal and Gruca (1993), in another study based on CBOE data, tried to identify patterns in the equity option market. They analyzed all transactions from the 1st July 1986 to 31st December 1986 for each option series along with the price of the underlying stock of the CBOE. They used parametric and non-parametric tests. They

concluded that the patterns observed in the equity option market were not completely consistent with the intraday patterns found in the equity market or other asset markets. More specifically, the equity option market presented a U-shaped pattern as far as the trade volume was concerned. Moreover, at the beginning of the day, transactions for call options were higher than for put options, but the bid-ask spread declined over the day, both for calls and puts.

Peterson (1990) looked for patterns in transaction volume in the option market in the CBOE by using F-statistics and heteroscedasticity-adjusted regressions. His data included the transaction data for the listed options of CBOE from 1983 to 1985. He found that the call returns increase at the end of the day, a pattern observed in stocks. More specifically, call returns are higher during midday Thursday and Fridays, and lower on Mondays. But for put options, the results are slightly different, as they show an increase in their returns during Mondays, Tuesdays, and Wednesdays. Also, put returns increase early on Thursday and Friday, but not during the middle of the day, as happens for stock and calls. Finally, puts show an increase in their returns during weekends, a pattern not observed for calls. Other authors, such as Ma et al (1988b) and Porter (1989), reached similar conclusions regarding intraday and intraweek seasonalities for bonds and futures.

In his research, Berkman (1992) tried to identify patterns in the option bid-ask spread during a trading day. He focused his studies on the EOE. The spread appeared to have a U-shaped pattern, a result of the level of investor uncertainty. This uncertainty is high in the morning and decreases in the middle of the day. Foester et al

(1990b) reached a similar conclusion, pointing out that at the opening of the market, there is a higher probability of insider trading than during the remaining of the day.

Cotner and Nayar (1993) observed seasonal effects on the S&P 100 Index Option, and more specifically a January effect, a monthly effect, and a day-of-the-week effect. They used a regression model using the ordinary least squares technique in order to observe seasonalities. Their data were the closing prices for call options on the S&P 100 index from October 10 1985 until the June 30 1989. The seasonal effects are more common in inefficient markets, including emerging markets. These seasonal effects influence the underlying prices of the index and cause the prices not to move in a random walk. Hansen and Lunde (2003) and Hellström (2003) concluded in their studies that several calendar effects are also observed in mature markets such as Germany, France and Hong Kong. The Black and Scholes Option Pricing Model (BSOPM) has an assumption stating that the underlying prices should move on a random walk basis in order to provide a fair value to the option.

These anomalies can also be caused by the market itself, due to the trading behaviour of the investors. In any case, they distort the fair value of options and therefore create arbitrage opportunities based on mis-pricing.

So far, a contradiction has appeared in our analysis. On one side, we have concluded that markets are efficient. On the other side, we have identified market anomalies, such as seasonalities, intra-day and intra-week effects, anomalies characterized as market inefficiencies. A potential explanation of this contradiction is that option markets themselves could be efficient if kept as isolated markets. But, because these markets are dependent to a high extent on the underlying markets, this

relation can create inefficiencies. It seems therefore that stock market anomalies are incorporated in option market behaviour and lead to price distortions.

4.2.7. Information asymmetry and insider trading

Information asymmetry and insider trading are important issues, and are interconnected as insiders have in their possession private information unknown to the rest of the investors. They can use this information to their benefit and therefore generate abnormal earnings. Information asymmetry and trading by insiders can also distort the behaviour of a market. This can be problematic for the market listed options behaviour or pricing.

4.2.7.1. Stock and option information asymmetry

For Naik (1993), the random manner in which information enters the market is an important issue. Krebs (1999) observed that there is a positive relationship between agent information and asset price volatility: if the quality of the information is good, then investors would feel safe to trade in the market, and this market will gain more investors. The greater the number of investors, the stronger the asset price movements are.

A model produced by Kim and Verrechia (1991) showed that when a scheduled macroeconomic news announcement causes a large price change, the post-announcement trading volume can be high or low, conditioned by three aspects of the

information. A large volume reaction can be caused by high information content in the announcement, or a high degree of information asymmetry between market participant, and/or a low amount of private information gathered before the announcement. Bhattacharya et al (2000) observed that there are many reasons for a market not to respond to firm announcements. It can be information inefficiency, or a firm not announcing value-added information, or that there are no (or low) legal restrictions on insider trading.

Richardson (1998), Schipper (1989) and Warfield et al (1995) have examined the relation between information asymmetry and manager earnings. According to these authors, there is a positive relationship between manager earnings and information asymmetry in seasoned equity offerings. This can be explained by the fact that the higher the asymmetric information, the greater the difficulty for investors to control management actions.

Option introduction seems to provide a solution to the problem of informational asymmetry because options positively affect information completion and risk sharing (Biais and Hillion, 1994). Option introduction decreases market breakdown problems caused by asymmetric information. Greater breakdown problems are more related to incomplete markets, so option introduction helps to complete the underlying market by providing greater informational efficiency. Why do options decrease breakdown problems? Informational inefficiency increases trading costs, so trading in such markets can be costly and dangerous. By introducing options, which provide further information to the market, markets become more informational efficient and less costly. But with options introduction, there is a risk that opportunities for insider

trading are created and therefore there might be a decrease in informational efficiency (Biais and Hillion, 1994).

Skinner (1989) also concluded that option listing provides greater informational efficiency to stocks. He reached this conclusion by observing that stocks with listed options presented reduced reaction to earning announcements. He also observed that stocks with listed options tend to be analyzed more heavily and by more analysts than the remaining stocks. This can be explained by the fact that analysts want to anticipate earning announcements in their price for these stocks.

Also, another benefit of informational efficiency is that option introduction makes the underlying asset exhibit stochastic volatility (Back, 1993). Stochastic volatility is useful because it can explain why it is that options with different strikes and expirations have different Black-Scholes implied volatilities i.e. it can explain the volatility smile.

Informational efficiency can be achieved at the moment that there are no legal constraints on short selling, and that investors are willing to enter such a strategy (Figlewski and Webb, 1993). Constraints on short selling can cause negative information to be overweighted by the market and to have as a consequence the underperformance of future share prices. The reason for stating this is that short selling provides signals to the market about the future movement of stock prices. However, the existence of options provides that informational efficiency into the market as through options, investors can make indirect short selling.

Kumar et al (1998) used data from all the stocks with listed options from CBOE, NYSE, the Pacific Stock Exchange and Philadelphia Stock Exchange from

1983-1989. They also underlined the benefits that option introduction offers to the primary market, mainly greater liquidity, lower information asymmetry, and greater pricing efficiency. But there is a negative aspect. Institutional investors could take large positions in both markets (option and primary) in order to take advantages of mis-pricing. These large positions could generate higher volatility to the underlying market and be dangerous, especially if a higher level of volatility is accompanied by period of higher uncertainty.

Chiras and Manaster (1978) observed that in efficient markets all possible available information is incorporated in share prices. So, the implied volatility from options should include not only any past prices but also any other available information. In addition, a weighted implied standard deviation (WISD) would provide even better results as it could weight the daily variances of stock price changes according to the price elasticity that the option has on these stock price changes. Their sample consisted of 23 monthly observation periods, from June 1973 to April 1975, for stocks with traded options on the CBOE. But, because the model refers to mature markets, it does not provide guidance regarding how to use models in emerging markets, where there is informational inefficiency.

Investor anonymity is also connected to the information level of the market. According to Garfinkel and Nimalendran (2003) and Benveniste et al (1992), investors' anonymity can positively influence volatility, informational efficiency and liquidity.

Finally, it should be noted that stock information asymmetry and insider trading are interrelated. They are both problems that all markets face, especially markets with

low legal investor protection (Charness and Garoupa, 1998). According to Benabou and Laroque (1992), insiders can sell private information at high costs or distort information, as there are no mechanisms to detect the distortions.

To conclude, let us note that stock markets can suffer from informational inefficiency or asymmetry. This can be generated by insider trading or market specifications. Option introduction provides the market with greater informational efficiency, directly or indirectly. The issue of the effects of information asymmetry on option markets has not been covered so far, but we can assume that stock market informational asymmetry could distort option fair value, because the quality of information affects the volatility, the transaction volume and the variance behaviour of the underlying asset.

But, as indicated earlier, informational asymmetry is also related to insider trading, which is the subject of the next section.

4.2.7.2. Insider trading

According to the literature, the restrictions on insider trading can be positive or negative. For Fishman and Hagerty (1992) and Del Brio et al (2001), insider trading decreases market efficiency, as insiders tend to show excess returns when they invest on corporate non-public information. Barclay and Warner (1993), who came to the same conclusion, described how profit-maximizing informed traders try to hide information by spreading trades into smaller transactions. Traders, when they have private information, want to trade in large volume to maximize profit. But other traders

can see large trades as a signal. Therefore, to camouflage large orders, traders can break them up into smaller trades. This is called stealth trading. Barclay and Warner categorized stock trades into small (100-499 shares), medium (500-9,999 shares) and large size (10,000 and more shares). They discovered that medium trades were associated with 92.8% of price during the sample period they examined. They concluded that informed traders tend to trade in medium size lots. Furthermore, Carter et al (2003) used daily returns data from 1991-94, for all traded firms listed on the NYSE, AMEX and NASDAQ. They concluded that there is a positive relationship between excess returns and the interval between insider trading and releasing the information to the public. Chakravarty et al (2003) identified the inefficiency that insiders can cause to the market. Having five years of observations (1988-1992) from 60 stocks from the NYSE and from the most traded options listed on the CBOE, they concluded that informed trading appears when option volumes are high and stock volumes are low.

However, for Cornell and Sirri (1992), Lustgarten and Mande (1998) and Bhattacharya and Nicodano (2001), insider trading increases market efficiency. This is based on the argument that insiders provide important information flows that can be quickly incorporated into share prices, hence giving an increase in market efficiency. For Seyhun (1990), insider trading is closely related to the size of the firm and the total number of traded shares. The insider trading tends to be more often in large firms. Also, Lutsgarten and Mande (1998) indicated that insider trading decreases errors from analysts and increases consensus.

For Bhattacharya and Nicodano (2001), the beneficial impact of insider trading can occur if insider equilibrium trades are small relative to the remaining traders' trades, and especially to those made by the liquidity-based trades. This positive impact is caused by the fact that insiders have private information at an interim date.

Bettis et al (2002) analyzed insider trading through the hedging use of collars and swaps, which are widely used by CEOs, board members, etc., and concluded that insider trading has positive effects on the market. Insiders, through their hedging strategies with collars and swaps, offer important information to other investors.

Charness and Garupa (1998), Benabou and Laroque (1992) and Bhattacharya et al (2000) considered in their studies that informational asymmetry and insider trading are correlated. The two first studies demonstrated that insiders can either sell private information at high costs or distort information, as there is no mechanism to recognize this distortion. Bhattacharya et al (2000) explained that there are many reasons for a market not to respond to firm's announcements. One of these is that there are only low legal restrictions for insider trading. Back (1993) agreed that informed traders, by their presence, affect option returns in a way not related to the underlying stock returns. Foster and Viswanathan (1990) presented almost the same observation. Finally, Cao et al (1998) found evidence of informed trading in the option market prior to takeover announcement.

4.2.8. Transaction volume and costs

Emerging markets are characterized by low transaction volumes and high transaction costs, creating high barriers to entry. In this section, we try to identify the potential implications of low volumes and high costs.

4.2.8.1. Transaction volume of options

According to Handa and Schwartz (1996), the only condition investors seek is liquidity. The higher the liquidity, the more investors are able to adjust their portfolios quickly and at low costs (Hasbrouck and Schwartz, 1988). In order to have depth, a market needs to present significant amount of orders, in terms frequency and quantity, which will cause only small price movements.

Kempf and Korn (1999) ran regressions using stock price changes as the dependent variable and best ask quotes, best bid quotes, transaction prices, transaction quantities for DAX futures nearest to deliver as the independent variables. The data were from DAX futures from September 1993 until September 1994. In their research regarding market depth analyzed by order size and stock price changes, they found that larger orders lead to small price changes and vice versa. This means that the relation between order size and stock price changes is non-linear. As a result, market depth cannot be measured by a single figure, and needs further consideration.

Detemple and Selden (1991) explained that in inefficient markets (or incomplete markets, as they like to characterize them), one cannot value options

independently from the underlying value. They also argued that the higher the number of traded contracts, the more complete the market is. Finally, they believed that a complete market needs two kinds of investors: risk-averse investors who perceive the option market as complementary to the primary market, and risk-taking investors who perceive the option market as a substitute to the stock market. The aggregate demand of these two kinds of investors has a double consequence: a fall in share return volatility, and a more stable market.

Derivative market transaction volume depends on the size of the primary market and its volatility (Corkish et al, 1997). George and Longstaff (1993) conducted important research on the bid-ask spread of options and its relation to the trading activity of these options. The market examined was the S&P 100 index. Specifically, they used a simple regression in two-equation and four-equation systems. The four regressions were: a) call bid-ask spread as dependent variable and call premium, liquidity of the call options, time to maturity and risk of call options as independent variables, b) call option liquidity as dependent variable and call bid-ask spreads, time to maturity and the squared difference between the spot index and call strike price, as the independent variables, c) put bid-ask spread as dependent variable and put premium, liquidity of the put options, time to maturity and risk of put options as independent variables, d) put option liquidity as dependent variable and put bid-ask spreads, time to maturity and the squared difference between the spot index and put strike price, as the independent variables. The first regression runs for the call bid-ask spread and call option liquidity, individually from the put bid-ask spread and put option liquidity. The second regression combines all four equations simultaneously.

The data in their study contains all the last-sale transactions and bid-ask quotes during 1989 for all the S&P 100 index options. They found a positive correlation between the bid-ask spread and option maturity and price, as well as a negative correlation with the trading volume. They therefore concluded that the bid-ask spread affects market makers' costs associated with the transactions. They also emphasised that market makers quote spreads in a way that reflects the information incorporated in other option spreads. This was supported by the fact that the bid-ask spreads of calls were positively correlated to puts trading activity, and vice-versa, as well as by the fact that the spreads between puts and calls were also positively correlated. Other researchers concluded that higher transaction volume leads to lower market makers' costs (Admati and Pfleiderer, 1988, Foster and Viswanathan, 1990 and Subrahmanyam 1990).

Finally, the fact that investors would buy puts and sell calls instead of selling short creates greater transactional efficiency (Figlewski and Webb, 1993).

As argued previously, transaction volume is an important determinant of the correct operation of any market. For a more complete stock and option market, a high transaction volume is required. But both option and stock emerging markets are characterized by low transaction volume, which can lead to high price movements. Therefore, the identification of this problem should be incorporated in the option price, or otherwise signs of market manipulation can be created for both stock and option markets.

4.2.8.2. Transaction costs

Leland (1985) tried to find a hedging strategy based on the Black-Scholes model, in order to incorporate transaction costs due to continuous “re-hedging” of a portfolio. He showed that there is such a strategy, but with assumptions that makes it fragile in real life trading. One assumption is that transaction costs remain bounded as the interval gets smaller. But the results of option pricing based on the strategy approached those coming from the Black-Scholes model when transaction costs were lower.

Transaction costs also have an impact when intervals between re-hedging situations diminish. This is justified by the fact that risk-averse investors are not willing to make a full hedge in order to save some of the transaction costs (Boyle and Vorst, 1992).

Finally, we can say that, even though option pricing models have an important impact on finding the fair value of options, market imperfections have a similar impact on these models. These imperfections are transaction costs and volume, indivisibility of the option contract and information asymmetry. Figlewski (1989) found that models that are mostly based on arbitrage are very weak when option prices are at their fair price and there is no arbitrage opportunity.

4.3. Conclusion

We have seen that stock markets and derivative markets can suffer from several inefficiencies. These inefficiencies are not only a characteristic of emerging markets, but also a characteristic of mature markets. Many studies have been conducted on the stock and derivative markets of the US, the UK, Germany and Japan, the four most important markets worldwide. But, despite the fact that they are characterized as 'mature', these markets also suffer from inefficiencies. These inefficiencies, or anomalies, may be identified as seasonalities, predictability, asymmetric information, insider trading, and market depth (transaction costs and volumes).

In certain periods during a trading year, stock and option markets appear to have signs of predictability and seasonality, such as the January effect, days-of-the-week effects etc. Additionally, evidence was found that many stock markets suffer from asymmetric information and insider trading. We assume that if there is asymmetric information in a market, then most probably it is due to insider trading. Views on this are somewhat mixed in the literature, as despite the fact that researchers identified asymmetric information as an anomaly, others argue that insider trading adds efficiency to the market. However, in the remainder of the thesis, we argue that asymmetric information and insider trading are anomalies.

Finally, we conclude that market depth can be inefficient. From the studies that we have analyzed regarding transaction costs and volumes, the conclusion was that the higher the transaction volumes and the lower the transaction costs, the more efficient the market. The argument for such a conclusion is that if transaction volumes are high

then less bias in pricing is observed in the market. Additionally, the lower the transaction costs the more able investors are to continuously re-hedge their positions and in general to make transactions in the stock and option market.

Having summarized our findings, we would like to point out one extra argument. Most of the studies identifying anomalies in stock and derivative markets have been conducted on mature markets. However, one would expect that mature markets, because they are complete markets, would not suffer from anomalies. Based on that remark, we argue that if mature markets do suffer from anomalies, then these same anomalies will be more accentuated in emerging markets. If such anomalies exist, then the efficiency assumption present in many asset-pricing models can be questioned.

CHAPTER 5: Methodology

5.1. Introduction

In this chapter, we discuss the methodology and the methods that will be used in the research. Clearly, a well-defined methodology is essential if reliable results are to be obtained. As stated in Chapter 1, the market under consideration is the Athens Derivatives Exchange (ADEX) and the option under examination is index option on the FTSE/ASE 20 index. The main variable to be analysed is the call premium for an at-the-money option with underlying asset the FTSE/ASE 20 index and 2 months to expiration. The purpose for choosing an at-the-money option contract with 2 months to expiration is that this is considered to be the most heavily traded option contract and so should provide us with more significant results.

In the second part of the chapter, the statistical tests used in the thesis are explained. This section includes a discussion of the meaning of the tests, why they were chosen and how they will assist the research.

The final part of the chapter consists of a description of the key variables included in the analysis. This is an important part as it gives the reader an understanding of which variables are under examination, how these variables are measured and why they were chosen.

5.2. Methodology

The literature review presented in Chapter 4 was the first major part of the research. The literature was selected from several journals and textbooks on the basis of the following criteria:

- the most appropriate articles for each of the literature review sub-sections
- primarily, articles from the most respectable finance journals
- articles from authors who are either pioneers or very commonly cited.

So in general this study uses ‘the best from the best’ i.e. the most respectable authors and the most respectable journals.

The literature review is extremely important as it helps us to assess the techniques used by other researchers and to formulate appropriate testable hypotheses.

The quantitative part of the study in Chapters 6 and 7 includes a statistical analysis of secondary data. In general terms, the research is deductive in character. Deduction is the process of generating testable hypotheses from existing theories. In this case, the deduction process is used to generate hypotheses concerning the possible problems that an emerging market, like the ASE, can cause to its listed derivatives market (the ADEX), based on the literature review of the subject. Next, the deduction process requires the testing of the selected hypotheses. This is also the intention of this research. After the hypotheses have been determined, they will be tested using a variety of statistical tests. The final step of the deduction process is the acceptance, rejection and, if necessary, the amendment of the hypotheses, depending on the empirical results obtained. The last major part of the research will also be quantitative, as it will try to find and implement statistical formulas to test the idea that stock and derivative market anomalies do have a significant effect on option prices in the Greek market.

In the main, the data used in the study are collected from secondary sources. The main advantage of secondary data is that they are usually less costly and less time-consuming to collect than primary data. But the collection of secondary data has

some limitations. The most important limitation concerns the accuracy of the data. The statistics collected may not exactly measure what the researcher requires and the information providers often do not accept responsibility for the completeness or accuracy of the information.

The secondary data employed in the study can be characterised as documentary and multiple-source data. Most of the information is collected from publications of the ASE, ADEX and the Greek Capital Market Committee and from specific Internet web-sites, as summarised in the References. These publications provided most of the statistical data used in the research. Unfortunately, not all of the required information was supplied free of charge.

We should comment at this stage that the data collected for the study might still carry some degree of inaccuracy. An effort was made to cross-fertilise the information from more than one source, but this was impossible to perform for the daily returns of the ASE, as the ASE statistical department was the only source for these data. The same problem existed with the ADEX information. We were reassured, though, that the data were free of inaccuracies and, as the ASE and ADEX are trusted public organisations, this may be true. Unfortunately, the Greek Capital Market Committee denied us access to data on insider trading using the excuse that such data were ‘top secret’ (when actually the data should be provided for research purposes). We overcame this problem by calculating statistical proxies for asymmetric information and insider trading. Thus, the figures that are presented as asymmetric information and insider trading were transformed from qualitative data to quantitative data using the dummy variable method.

The data consists of 500 daily observations from the ASE and ADEX.

5.3. Methods

The study includes tests for ASE efficiency, the ASE's suitability for normal-theory models, for the BSOPM and for put-call parity. The final test is a regression that includes the BSOPM's variables plus the variables that cause pricing problems to option contracts. A more detailed analysis of such tests follows. The tests which are analysed below are performed not only for the whole set of data, i.e. from 9/2000 – 9/2002, but also for each individual year, i.e. 9/2000 – 9/2001 and 9/2001 – 9/2002. The justification for the use of the tests on each individual year is that in mid 2001 Morgan Stanley announced that they would advance the ASE to 'mature market' status.

5.3.1. Tests of ASE efficiency

The first group of tests include efficiency tests on the ASE. The purpose of such tests is to assess the efficiency of the ASE. The tests are split into three groups, namely tests for weak-form efficiency, tests for semi-strong form efficiency and tests for strong form efficiency.

The data used for these tests are the 500 daily observations of the FTSE/ASE 20 index for the period 9/2000 – 9/2002 and data from various corporate and government announcements regarding the firms listed in the index and the market itself, for the same period.

The weak-form efficiency tests include a random walk test, a runs test, Ljung-Box test for independence and a seasonality test. The random walk test is performed by means of a regression in which we regress the index level on its lagged value. The

runs test and the Ljung-Box test provide evidence as to independence between the index prices. Finally, seasonality tests are performed as these also test for weak-form efficiency in a market. The seasonality tests investigate days-of-the-week and months-of-the-year effects. To perform such tests, we created appropriate dummy variables (an explanation of the dummy variable construction is included in the variables' analysis section) and regressed the index returns on the dummies. In addition to the regression analysis, we also calculate the average returns for each day and for each month. Based on these calculations we perform an F-test to investigate whether there is a significant difference between the average returns of different weekdays or different months.

Semi-strong form efficiency is tested with a volatility test. Implied volatility is derived from the BSOPM. However, in an efficient market, implied volatility should equal true (or historic) volatility, as if markets are efficient the predicted volatility should fit the actual. The two volatilities must be equal in order not to create pricing problems for options. The calculation of the annualized standard deviation of the daily change in the logarithms of the FTSE/ASE 20 index over a 60-days period provides the daily true (historic) volatility.

Having calculated true volatility, we performed a Wilcoxon Signed Rank test on the implied volatility and the true volatility. Furthermore two more tests were used for testing volatility: a regression analysis between implied and true volatility and a correlation test between those two variables.

Apart from the test between the implied and true volatilities we conduct one further test. We estimate a GARCH model for the FTSE/ASE 20 index. If the ASE is semi-strong form efficient, then no volatility clustering is expected to be found (Panagiotidis, 2003).

A test for asymmetric information will assist us to test for strong-form efficiency. The method for generating an asymmetric information variable is described in Section 5.4. In this case, we investigate whether the ASE suffers from asymmetric information.

We use t-tests and Wilcoxon Signed Rank tests for variables that are normally and non-normally distributed, respectively.

Tests for insider trading would also have been useful. However, as we have mentioned already, the Greek Capital Market Committee refused to supply such data. However, as insider trading and asymmetric information are closely related we assume that if asymmetric information is entering the market, then insider trading is taking place. Based on that assumption, it follows that if the market suffers from asymmetric information, it is not strong-form efficient.

5.3.2. ASE suitability for normal-theory models

For these tests on the ASE, we perform volatility tests and normality tests. As above, the data used are 500 daily observation of the FTSE/ASE 20 index from the ASE for the period 9/2000-9/2002.

Additional tests for market normality include tests such as skewness tests, kurtosis tests and Jarque Bera tests. Normality tests are important as BSOPM assumes that the underlying asset price is normally distributed. So it is important to test for normality, as if it does not hold for the ASE, this would seriously question the suitability of the BSOPM in the Greek market.

The normality tests are divided into three categories. These categories are the whole set of data, the continuous trading days (i.e. Monday-Friday) and the two day's

break days (i.e. Friday-Monday). The reason for dividing the data into these three categories is that usually during the weekends information enters the markets but cannot be incorporated into stock prices as the market is closed. This information could create a jump in the index between Friday's closing prices and Monday's opening prices. So by dividing the sample into the continuous trading and two day's break trading we can observe any non-normality.

Finally, tests of skewness, kurtosis and the Jarque-Bera test are applied to the first differences of the index prices and on the actual index prices. The reason for taking differences, as well as the actual prices, is that the change of the index level transforms the data into a stationary series and stationary data provide more reliable results.

5.3.3. Put-call parity tests

Put-call parity is fundamental in any derivatives market in order to avoid arbitrage trading. The tests will be performed with and without the inclusion of transaction costs. The reason for including transaction costs is that even if there is an arbitrage opportunity between the put and call premiums, this opportunity could be eliminated by transaction costs. Furthermore, there is another distinction between the tests. We test the parity, first, with the spot prices of the FTSE/ASE 20 index in the formula, and secondly with the future prices of the FTSE/ASE 20 index in the formula. A Wilcoxon Signed Rank test and t-test will assist us to conclude whether put-call parity holds or not for the ADEX market. The use of t-tests and Wilcoxon Signed Rank tests depends on whether the variables are normally or non-normally distributed, respectively.

5.3.4. BSOPM validity testing

The BSOPM, as has already been shown, has been criticised in many studies as an invalid model. So, in this part of the research, we aim to test the validity of the model.

The data which will be used will be the 500 daily observations of call premiums, the risk-free rate, measures of implied and true volatility, calendar days to expiration, trading days to expiration, future prices of the FTSE/ASE 20 index and the spot prices of the FTSE/ASE 20 index. After calculating the theoretical call premiums on all variations, there will be tests on the difference between the market call premiums and each of the BSOPM variations. If the model is valid then the theoretical premiums should not be significantly different from the market premiums. Once again, the Wilcoxon Signed Rank test will assist us in testing for statistical significance, as our variables are non-normally distributed. We also apply a Wilcoxon Signed Rank test to the call and put implied volatilities, due to the non-normality of the variables. According to the BSOPM, if they have the same strike price, underlying asset and time to expiration, then these two options' implied volatilities must be equal.

5.3.5. Multiple regression analysis

One of the main objectives of this thesis is to investigate the effect of market anomalies on option prices. In order to achieve this, we construct a multiple regression model. Having estimated the variables that seem from the literature to have an influence on the fair pricing of option contracts, we incorporate them into the

model as independent variables. The dependent variable will be the market price of an option contract. Before the estimation of the regression equation, unit root tests on the variables will take place. The reason for using unit root tests is to conclude whether to use regression analysis or cointegration. Additionally in order for the model to be valid, its variables need to be integrated of the same order. The augmented Dickey-Fuller test is used to test for unit roots. The augmented Dickey-Fuller (ADF) statistic, used in the test, is a negative number. The more negative it is, the stronger the rejection of the hypothesis that there is a unit root at the 90%, 95% and 99% levels of confidence.

Once estimated, the regression residuals will be tested. Tests on residuals are important as they provide information as to the validity of the model. We will also test the stability and predictability of the regressions through the Chow Forecast and Chow Breakpoint tests. Finally, the predicted option prices from the regression model and the predicted option prices from the BSOPM will be compared. The purpose of this comparison is to investigate whether the regression model predicts closer prices than the BSOPM, enabling us to conclude that market anomalies do have a significant effect of market option prices. The statistic to be used for such a comparison will be the Root Mean Squared Error.

5.4. Analysis of variables

The final section of this chapter presents a description of the key variables used. We begin with an explanation of the simple raw data and finish with the data that were either calculated or transformed by the researcher.

The variables are the following (all data refer to the same period, i.e. 9/2000 to 9/2002):

1. Spot prices of the FTSE/ASE 20 index.
2. Futures prices of the FTSE/ASE 20 index.
3. Call and put premiums for the at-the-money index option with underlying asset the FTSE/ASE 20 index and with 2 month to expiration.
4. Two months Euribor interest rates. The specific interest rates were chosen as the risk free rate, due to the fact that they are the European Interbank Official Rates and so can be considered as risk free. A two months rate was chosen in order to fit the expiration date of the option contracts.
5. Daily transaction volumes for the index and the call options.
6. Daily transaction costs for the index, the call and the put options.
7. Daily implied volatility for the specific option contracts, which was provided by Bloomberg.
8. Daily true volatility
9. Dummy variable for asymmetric information¹ and insider trading.
10. Dummy variables for seasonality tests.
11. BSOPM in various variations.

The first four variables and the implied volatility comprise the BSOPM's variables.

The remaining variables are the various market anomalies and elements that will be used in the several tests of the thesis.

¹ Asymmetric information includes insider trading as we do not distinguish between these two anomalies based on the argument that in order to utilise non-publicly available information, traders should be insiders.

5.4.1. Calculation of variables

5.4.1.1. Transaction costs

The transaction costs that are included as a variable are calculated based on the figures provided by the ADEX. Transaction cost for the index is 0.2% of the index level and for option contracts are €6 for each contract (i.e. put and call).

5.4.1.2. True volatility

The true volatility was calculated in order to test it against the implied volatility, which is used for the BSOPM. The true volatility is the annualised standard deviation of the 60 daily changes in the log-index.

5.4.1.3. Volatility estimation by ARCH and GARCH

In addition to the test between true volatility and implied volatility, we estimate volatility through an ARCH and GARCH model (Engle, 1982, Bollerslev, 1986). In order to estimate ARCH and GARCH models we need to estimate two specifications, i.e. one for the conditional mean and one for the conditional variance.

A standard GARCH model is GARCH (1,1):

$$y_t = \alpha y_{t-1} + \varepsilon_t \quad \text{mean equation}$$

$$\sigma_t^2 = \omega + \beta \varepsilon_{t-1} + \gamma \sigma_{t-1}^2 \quad \text{variance equation}$$

The mean equation is a simple random walk equation with an error term. The variance equation shows that the variance depends on the mean equation (ω), the lagged value of the error term (which is estimated from the mean equation) and the lagged value of the variance. The GARCH is (1,1) as it depends on the previous time period in both the error term and variance. The first number is the ARCH term and the second is the GARCH term.

5.4.1.4. Asymmetric information and insider trading

An attempt was made to produce separate dummy variables for asymmetric information and insider trading, but these were unsuccessful. So the decision was taken to incorporate the measurement of asymmetric information and insider trading into one dummy variable. The reason for producing one variable for two kinds of data is that, based on the literature review, if there is insider trading then at the same time there is asymmetric information and vice versa. In order to create the variable, we calculated index returns and the standard deviation of the returns. According to the normal distribution, 95% of all prices should be included within 2 standard deviations of the mean. So each daily return that was found outside the range of the 2 standard deviations could be due to two reasons i.e. either due to a random effect or due to asymmetric information and insider trading. Having identified those daily observations that were outside the range, we searched within a period of one week to see whether there was any important information (e.g. dividend announcement, earnings announcements, publication of the balance sheet, any buy-out, important deals etc.) in the market that would be likely to affect the index's listed shares. If there were such information during that period, then we considered that observation as a day with asymmetric information. Since asymmetric information and insider trading

can cause the index to rise or fall, we divided the asymmetric information days into two variables (asymmetric information – drop (AID) and asymmetric information – up (AIU)) according to the fluctuations in the index. So,

$AID = 1$ and $AIU = 0$, if there was a drop in the index deemed to be caused by asymmetric information and insider trading.

$AID = 0$ and $AIU = 1$, if there was a rise in the index deemed to be caused by asymmetric information and insider trading.

$AID = 0$ and $AIU = 0$, otherwise.

5.4.1.5. Seasonality effects

For seasonality effects, we performed tests for days-of-the-week and months-of-the-year. To investigate the days-of-the-week effects, we created five series, one for each trading day of the week. We placed the figure 1 for Monday if the observation was on Monday and 0 otherwise. We did the same thing for all the remaining days. Having devised the five dummy variables in this way, we then ran a regression with the index returns as the dependent variable and the five dummies as independent variables. A similar method was followed to investigate the months-of-the-year effects.

5.4.1.6. Variations of the BSOPM

The variables that are included as the BSOPM variations are the following:

$BSSPIMV = BSOPM$ theoretical prices which are calculated based on the spot index and implied volatility

BSSPTV = BSOPM theoretical prices which are calculated based on the spot index and true volatility

BSFPIMV = BSOPM theoretical prices which are calculated based on the future index and implied volatility

BSFPTV = BSOPM theoretical prices which are calculated based on the future index and true volatility

When stating that the BSOPM variations were based on the future index or the spot index and based on the implied and true volatility, we mean that the underlying asset is either the futures price or the spot price of the index and that the volatility measure is either the implied volatility or the true volatility.

The underlying reason for using the BSOPM's variations is, as we have argued since the beginning of the thesis, that anomalies create inefficiencies in the model so these anomalies should be able to explain some of the variation of the option prices. In addition, we argue that if these anomalies do explain some of the variation in option prices, then they should be incorporated into the model. As we have already mentioned, there will be several variations of the BSOPM as pricing problems could arise from any of the model's variations. The BSOPM will be examined, as we can see from above, based on the implied volatility and true volatility and based on future prices and spot prices of the underlying asset.

5.5. Hypotheses to be tested

This chapter ends with a brief outline of the hypotheses that will be tested in the empirical part of the thesis.

As mentioned in the introduction, Chapter 6 includes all the tests that have been performed on the ASE, the ADEX and the BSOPM.

So the hypotheses to be tested are:

H₁: ASE is strong form efficient

H₂: ASE is semi-strong efficient

H₃: ASE is weak form efficient

H₄: ASE's index is normally distributed

H₅: ASE is appropriate for normal theory models

H₆: Theoretical call premiums are not significantly different from market premiums

In chapter 7, there are tests on the effect of the market anomalies on the option prices. In general terms, the null hypothesis to be tested is the following:

H₇: Market anomalies do not influence the call premiums

Having estimated, through the regression, the variables that affect the call option premiums, then the null hypothesis for the regression's residuals will be:

H₈: Residuals are white noise i.e. residuals are uncorrelated and have a mean of zero

And finally for the validity and predictability and stability of the final regression model, the null hypotheses to be tested are:

H₉: The significant market anomalies do not have on aggregate a significant effect on option prices

H₁₀: A sub-sample of 250 observations can predict the values for the remaining sample

H₁₁: There is no structural change between the year 2000/01 and 2001/02 in the regression results

H₁₂: The regressions fitted values produce better results compared to the BSOPM theoretical prices.

5.6. Conclusion

The methodology is crucially important for any research test. This chapter has described the methodological approach to be adopted in the research, and presented in general terms the statistical methods to be applied. Where necessary, a more detailed discussion of the techniques and their applicability will be given in the following chapters. Finally, we have described the variables that are used throughout the study and explained why these variables were chosen.

CHAPTER 6: Testing ASE, ADEX and BSOPM

6.1 Introduction

In this chapter, we investigate the efficiency of the ASE and ADEX and test the validity of the BSOPM in the Greek market. Through the tests on the ASE and ADEX, we are able to assess some of the most important assumptions of the BSOPM – in particular, those concerning the efficiency and normality of the underlying index, and implied volatility. We also consider the extent to which the ASE is an emerging market and therefore inappropriate for normal-theory models. Additionally, we try to show, through the tests on the BSOPM's assumptions that the model's prices differ significantly from market prices. The chapter ends with a discussion of whether option pricing errors are due to the ASE inefficiencies, ADEX inefficiencies and/or the BSOPM assumptions.

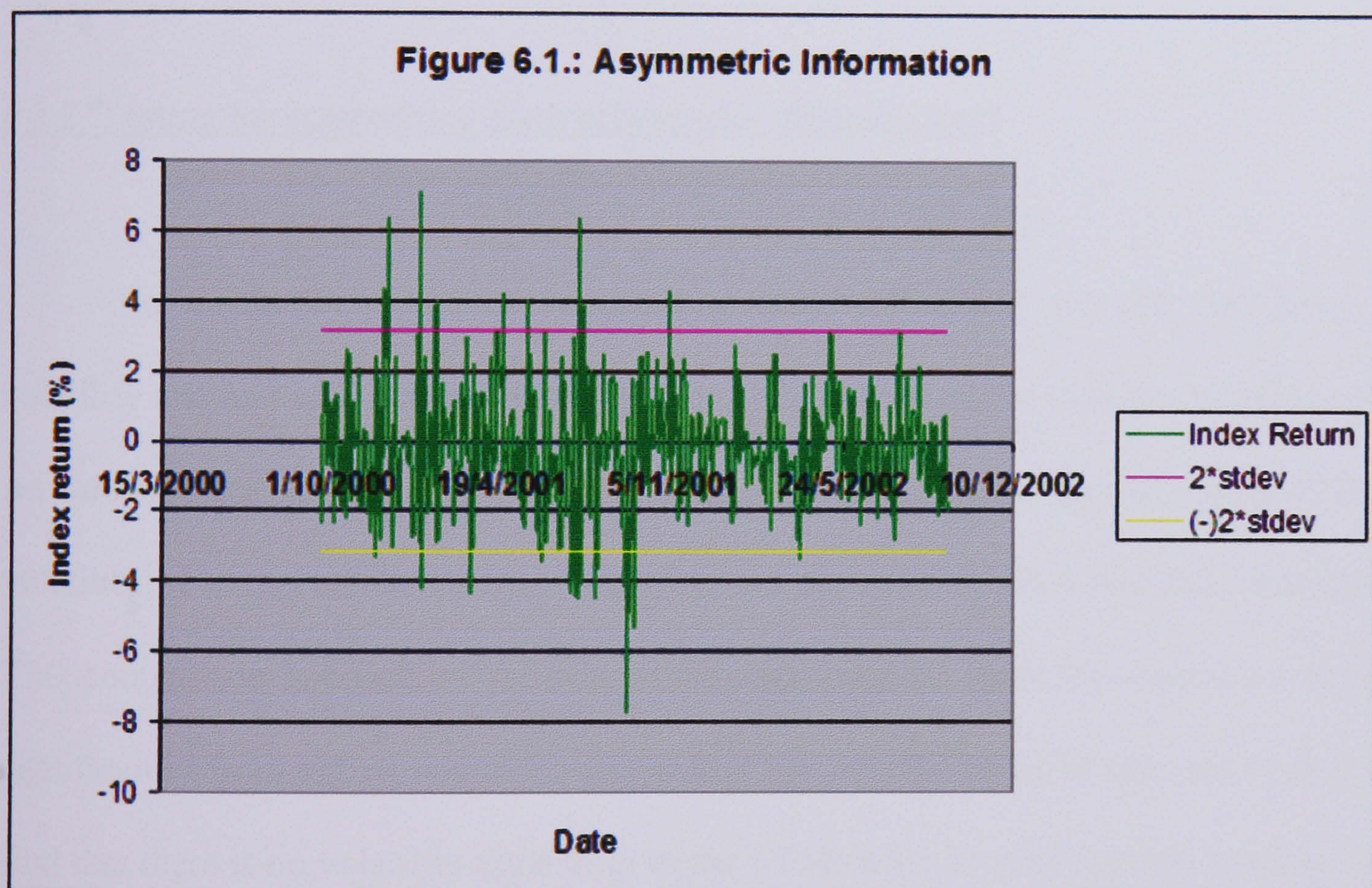
6.2. Testing the efficiency of the ASE

The tests in this part of the study are divided into tests for strong, semi-strong and weak form efficiency. In addition, we conduct efficiency tests on the ASE for the two years under examination (2000-2002) and for each of the two years individually (2000/01 and 2001/02). One of the reasons for conducting the tests for each year is that Morgan Stanley announced that from mid 2001 they would advance the ASE from 'emerging market' status to 'mature market' status. So we want to test whether the ASE actually became a more efficient market in 2001/02.

6.2.1. Testing for strong form efficiency - asymmetric information

To assess the ASE for strong efficiency, we apply a test designed to identify the extent of asymmetric information. Here we have to note again that the measurement of asymmetric information is the same as our measurement of insider trading on the assumption that it is insider traders who have access to and act upon private information (see chapter 5 for an explanation of the measurement of asymmetric information).

We start our analysis from Figure 6.1, which is shown below.



The green line represents the daily returns of the FTSE/ASE 20 index. The purple and yellow lines represent upper and lower borders equal to the mean return plus or minus two standard deviations. As can be seen, several daily returns are outside these borders. Taking into account our further analysis of corporate and government announcements regarding listed firms and the stock market, we take this as evidence that the ASE suffers from asymmetric information, which in turn suggests

that the ASE is not strong form efficient. As explained in Chapter 2, in order to be strong form efficient, all information (including private information) should be reflected in the stock price and the use of such information should offer no abnormal returns.

In Appendix 5, we can see the asymmetric information graphs for each year. Based on these two graphs, we can conclude that the ASE is not strong form efficient in either year. However, it is noticeable that in the year 2001/02 there are fewer daily returns outside the borders, which in turn suggests that there is some improvement in the efficiency level of the ASE in 2002.

6.2.2. Testing for semi-strong form efficiency - volatility tests

To assess the ASE for semi-strong form efficiency, we use two tests: a volatility test and a GARCH test (Bollerslev, 1986). In order to perform the first test, we calculate true volatility (see Chapter 5 for an explanation of the calculation of true volatility). Having estimated true volatility, we compare implied and true volatility. This comparison is based on the assumption that implied volatility should not differ significantly from actual volatility. Regarding the ARCH/GARCH test, we expect to find that there is no volatility clustering in the FTSE/ASE 20 index and its returns (see Panagiotidis, 2003).

6.2.2.1. Implied and true volatility

We use the Wilcoxon Signed Rank test to check whether the mean of implied volatility (\overline{IMV}) is significantly different from the mean of true volatility (\overline{TV}).

We have:

$$H_0: \overline{IMV} = \overline{TV}$$

$$H_1: \overline{IMV} \neq \overline{TV}$$

The results are shown in Table 6.1.

Table 6.1: Wilcoxon signed rank test results - Implied vs True Volatility

	2000-2002	2000-2001	2001-2002
Wilcoxon W-statistic	8515	3073	800
prob.	0.0001	0.0002	0.0003

As we can observe, the W-statistic is 8515 for the two-year period, which is highly significant at the 1% level, and so allows us to reject the null hypothesis. The same result applies for each individual year. By rejecting the null hypothesis, we are able to say that there is a significant difference between true and implied volatility. A reason for this result could be that the market is unable to predict true volatility correctly due to inefficiencies in the market.

Secondly, we estimate the following regression equation:

$$TV = a_0 + a_1 IMV + e$$

The hypotheses to be tested are:

$$H_0: a_0 = 0 \text{ and } a_1 = 1$$

$$H_1: a_0 \neq 0 \text{ and/or } a_1 \neq 1$$

The regression results are shown in Table 6.2.

Table 6.2: True volatility regressions result

Dependent Variable: TV	2000-2002		2000-2001		2001-2002	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Method: OLS						
C	0.05	5.68*	0.27	13.53*	0.009	1.25
IMV**	0.65	-12.67*	0.10	-16.72*	0.75	-10.12*
R-squared	0.54		0.01		0.79	

*significant at 5% level

**NOTE: t-statistics for IMV test for a significant difference from 1 using the formula:

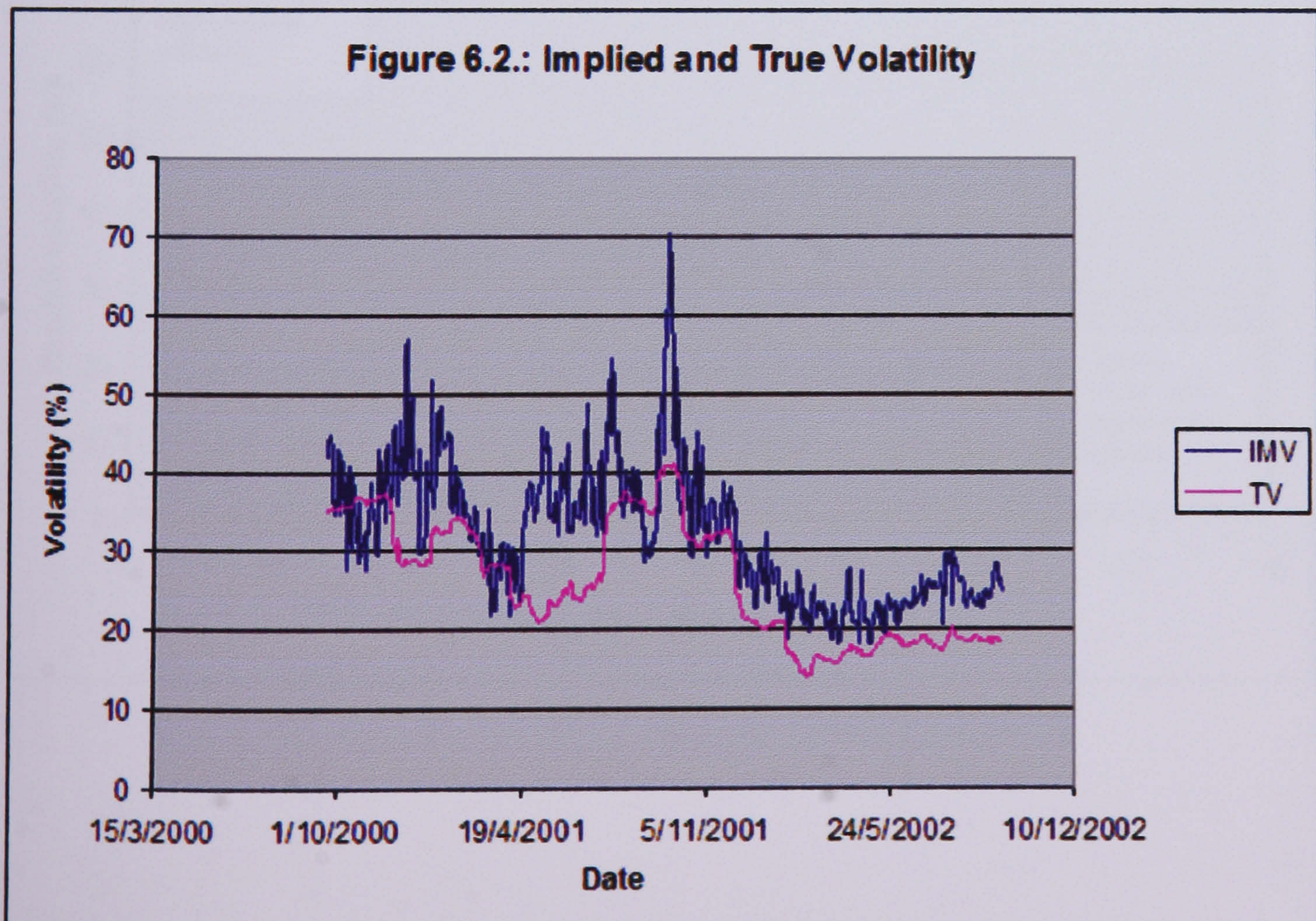
$$t\text{-statistic} = \frac{\text{coefficient} - 1}{\text{st. error}}$$

The results show that we can reject the null hypothesis that $a_1 = 1$ for the two-year period and for the individual years. By rejecting the null hypothesis, we can conclude that implied volatility is not a good predictor of true volatility. However, IMV is clearly a better predictor of TV in the year 2001/02 (where R^2 is 0.79) than in the first year (where R^2 is only 0.01). But over the two years, we can see that they tend to move in the same direction. This is a conclusion that can be also drawn from Figure 6.2 and from the correlation coefficient, which is 0.74 (see Appendix 6).

Furthermore the Chow breakpoint test's result supports the conclusion that there is a structural break in the two years. However this could be due to the fact that in 2000/01 the constant is significant, yet in 2001/02 it is not. The results are presented below:

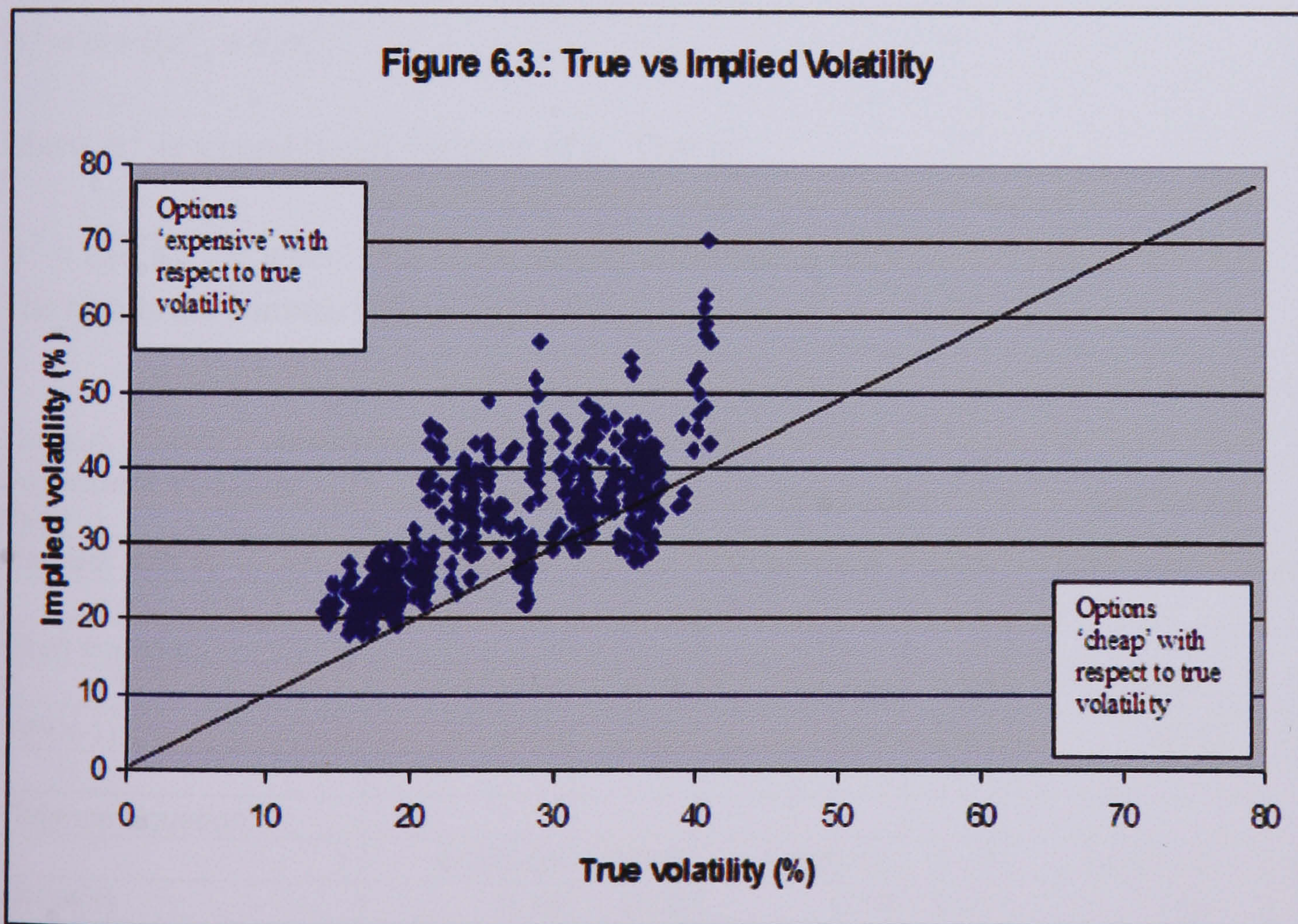
Table 6.3: Chow Breakpoint test results on true volatility regression

F-statistic	116.07	Prob.	0.00
Log likelihood ratio	191.96	Prob.	0.00



In addition to the Wilcoxon signed rank test, the regression analysis and the Chow breakpoint test, we conduct another test in which we measure the gap that is created between the true and implied volatility (see Figure 6.3) and the effect of this gap in option pricing. On this graph we are to observe that, based on implied volatility, options are more expensive. In other words, based on the implied volatility, most of the at-the-money options are overpriced, which means that there is evidence of pricing problems.

In Appendix 7, the graphs show the overvaluation or undervaluation of option contracts for each year individually. It is clear that, based on implied volatility, options are more expensive in both years. However, in 2001/02 almost all the options are overpriced, whereas in the first year some of the options are underpriced as well.



6.2.2.2. Volatility estimation from the GARCH(1,1) Model

The efficient market hypothesis predicts that in efficient markets, the returns on securities are not correlated over time. Thus, information on a security's return today does not help investors to forecast the security's return tomorrow. It follows that in an inefficient market we would expect to find evidence of volatility clustering (so that abnormally high returns on one day are likely to be followed by abnormally high or low returns the next day). To investigate this, we test the FTSE/ASE 20 index returns for generalised ARCH effects. We assume a GARCH (1,1) model and estimate the following equations:

$$RIND_t = a_0 + b_1 RIND_{t-1} + e_t$$

$$\sigma_t^2 = \omega + \theta_1 e_{t-1}^2 + \theta_2 \sigma_{t-1}^2$$

where, σ_t^2 is a conditional variance of e_t . That is:

$$\sigma_t^2 = E(e_t^2 | \Omega_{t-1}), \text{ where } \Omega_{t-1} \text{ is the lagged information set.}$$

The results are summarised in Table 6.4.

Table 6.4: ARCH and Generalised ARCH results

Dependent Variable: RIND	2000-2002		2000-2001		2001-2002	
	Coefficient	prob.	Coefficient	prob.	Coefficient	prob.
Method: ARCH						
<i>Mean equation:</i>						
C	-0.0013	0.05	-0.002	0.11	-0.001	0.16
RIND(-1)	0.13	0.02	0.11	0.17	0.14	0.03
<i>Variance Equation:</i>						
C	4.20E-05	0.002	9.48E-05	0.10	3.06E-05	0.07
ARCH(1)	0.16	0.00	0.18	0.01	0.05	0.13
GARCH(1)	0.67	0.00	0.56	0.01	0.72	0.00

From the regression equation estimates for the two-year period, ARCH and GARCH effects are significantly different from zero. We conclude from the GARCH

(1,1) model that there is volatility clustering in the FTSE/ASE 20 index. This is an indication that the market is not semi-strong efficient.

Also, GARCH effects are significantly different from zero for both years. However, ARCH effects are only significant in 2000/01, suggesting some improvement in the extent of volatility clustering in the FTSE/ASE 20 index in 2001/02.

In conclusion, we can say that the market seems to be unable to predict true volatility correctly and this is a very important issue as the BSOPM assumes that implied volatility is a good approximation of the true volatility. As there is a significant difference between the two volatilities, we can argue that the market is not semi-strong efficient and we can also argue that the implied volatility assumption of the BSOPM does not hold. Finally, we observe volatility clustering, which is another indication of inefficiency.

6.2.3. Tests for weak form efficiency

To assess the ASE for weak form efficiency, we apply four sets of tests: a random walk test, a runs test, an independence test and seasonality tests.

6.2.3.1. Random walk test

If the ASE were weak form efficient, then we would expect the FTSE/ASE 20 index to follow a random walk, meaning that index prices are independent, so that past prices cannot be used to predict future ones. The index IND_t is said to follow a random walk if:

$$IND_t = a_0 IND_{t-1} + e_t$$

with $a_0 = 1$. In order to test for a random walk, therefore, we test whether a_0 is significantly different from one.

H_0 : $a_0 = 1$, then the FTSE/ASE 20 index is a random walk

H_1 : $a_0 \neq 1$, then the FTSE/ASE 20 index is not a random walk

The results of an OLS regression are shown in Table 6.5.

Table 6.5: Random walk results

Dependent Variable: IND	2000-2002		2000-2001		2001-2002	
Method: OLS	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
IND(-1)**	0.997	-2.72*	0.997	-2.61*	0.999	-1.27
*significant at 5% level						
**NOTE: t-statistics for IND(-1) are for significant difference from 1 using the formula:						
$t\text{-statistic} = \frac{\text{coefficient} - 1}{\text{st. error}}$						

We also perform a Chow breakpoint test in order to test for any structural break between the two years of the study. The results are shown below:

Table 6.6: Chow Breakpoint test results on Random Walk

F-statistic	1.05	Prob.	0.30
Log likelihood ratio	1.06	Prob.	0.30

From the random walk results, we conclude that the ASE index is not a random walk, which suggests in turn that the ASE is not weak form efficient. However the regression result for each individual year suggests that in 2001/02 the index is a random walk. So, we can argue that the ASE had an increase in efficiency level in the second year, meaning that it seems to become weak-form efficient. Even so, the Chow Breakpoint test result does not indicate a structural break between the two years.

6.2.3.2. Runs test

This test checks for independence between the current value of a variable and its lagged values: $X_t, X_{t-1}, X_{t-2}, \dots, X_{t-n}$. If a series is weak form efficient then the lagged values must be independent. To compute a runs test, we compute the following:

$$E(R) = \frac{2N_1N_2}{N_1 + N_2} + 1$$

$$\sigma = \sqrt{\frac{2N_1N_2(2N_1N_2 - N_1 - N_2)}{(N_1 + N_2)^2(N_1 + N_2 - 1)}}$$

where N_1 = number of positive returns of the index and N_2 = number of negative returns of the index.

The test for significance is a t-test: $t = \frac{R - E(R)}{\sigma}$, where R is the total number

of runs, $E(R)$ the expected number of runs and σ the standard deviation. We have:

H_0 : the current and lagged values of the index are uncorrelated

H_1 : the current and lagged values of the index are not uncorrelated

Table 6.7: Runs test results

	2000-2002	2000-2001	2001-2002
	t-statistic	t-statistic	t-statistic
Runs Test	-3.535*	-3.15*	-1.57
*significant at 5% level			

For the two-year period, t-statistic = -3.535, which is significant at the 5% level. Hence, the index seems not to be uncorrelated, which provides us with further evidence that the ASE is not weak form efficient. However, the test shows that in the

second year the t-statistic is not significant. So, again, we have some evidence of an improvement in the efficiency level of the ASE. It seems that in 2001/02, it may have been weak form efficient.

6.2.3.3. Ljung – Box test for independence

Another test for weak form efficiency is the Ljung–Box test. This test produces a Q-statistic where:

$$Q(k) = T(T + 2) \sum_{m=1}^k (T - m)^{-1} \rho^2(m)$$

where T is the number of observations, k is the number of lags being tested, m is the i th lagged value and ρ is the correlation coefficient between the index prices. We have:

$$H_0: \rho(1) = \rho(2) = \rho(3) = \dots = \rho(k) = 0$$

$$H_1: \text{at least one } \rho \text{ is not } 0$$

The results can be seen in Table 6.8. below:

Table 6.8.: Ljung-Box test results

	2000-2002	2000-2001	2001-2002
	Q-statistic	Q-statistic	Q-statistic
ASE	491.70**	238.81**	244.95**
**significant at 1% level			

As we can see from the Q-statistic, the results are all significant, meaning that at least one of the ρ is not 0. Furthermore, in Appendix 8, the correlogram for the FTSE/ASE 20 suggests that the series is AR(1). From this result, we can conclude that the index is not weak form efficient as there is evidence of autocorrelation.

6.2.3.4. Seasonality tests – Calendar effects

In order to test for seasonality, we consider day-of-the-week and month-of-the-year effects.

Day-of-the-week effects

An examination of Figure 6.4 shows that Friday is the only day that has positive average returns, and Tuesday is the day that has the highest average losses.

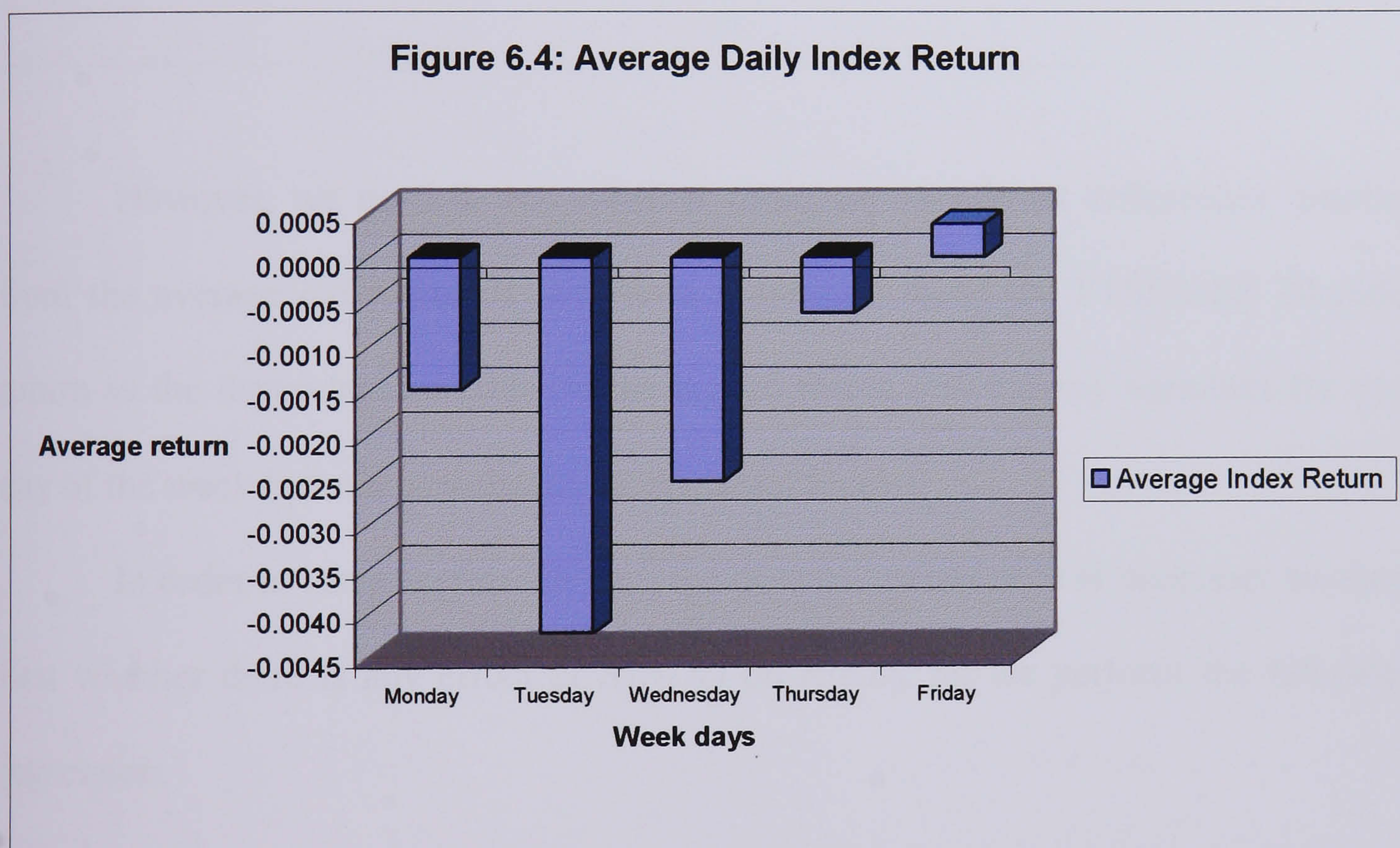
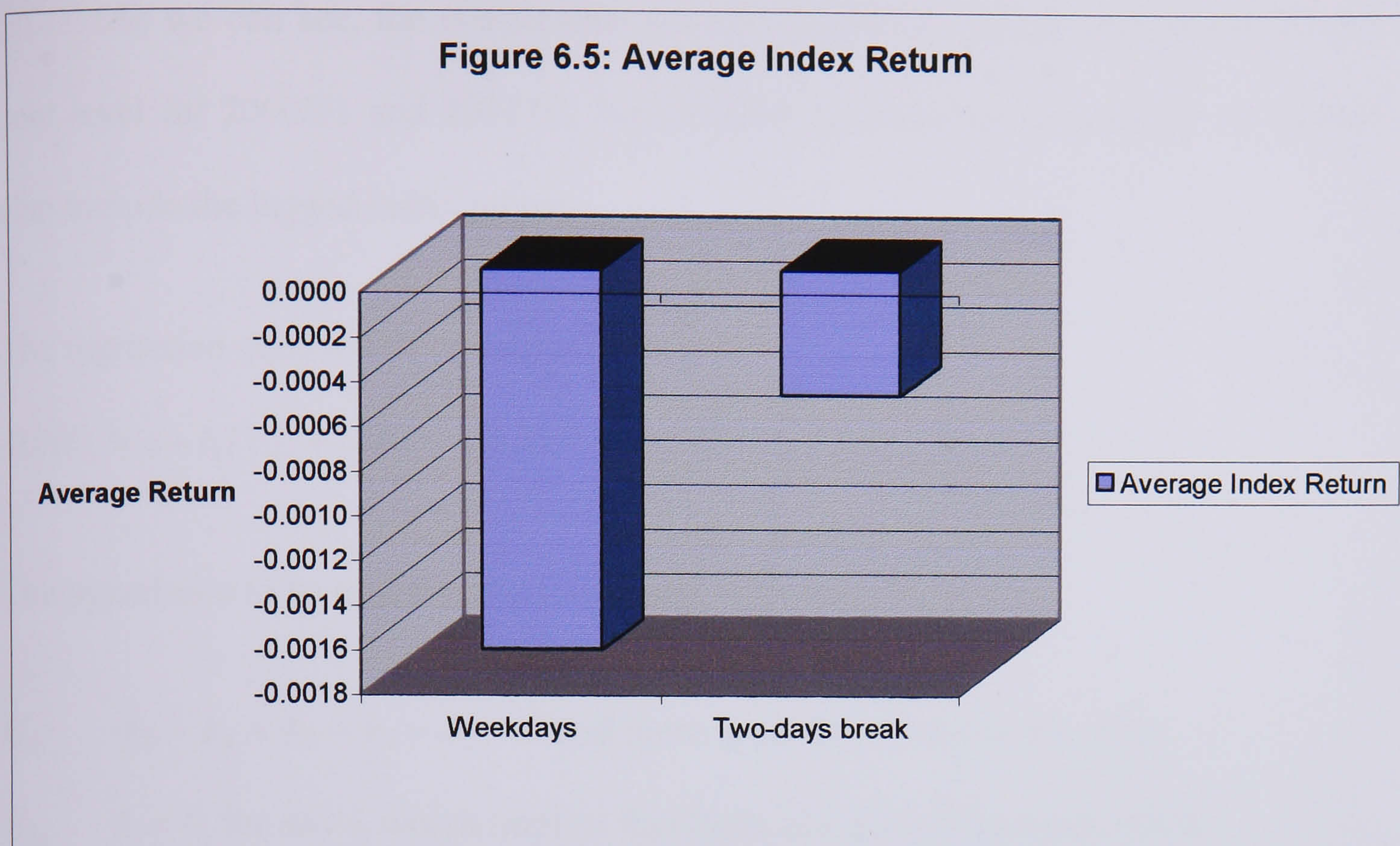


Figure 6.5 compares the average returns between continuous trading (i.e. Monday to Friday) and two days' break trading (i.e. Friday to Monday). As we can see, there is a difference between the two average returns as in continuous trading average losses are much higher than in two days' break trading.



However, we need to test whether these are significant differences. Starting from the average daily returns, we run a regression using the FTSE/ASE 20 index return as the dependent variable on the lagged return and dummy variables for each day of the week (except Monday as independent factor).

In order to run a regression with the dummy variables, it is necessary to check first whether there is any effect of $RIND_{t-1}$ on $RIND_t$. So we perform the following regression:

$RIND_t = a_0 RIND_{t-1} + e_t$, where $RIND_t$, $RIND_{t-1}$ are the index returns at time t and $t-1$ respectively.

The regression results are shown in Table 6.9.

Table 6.9: *RIND* regression result

Dependent Variable: <i>RIND</i>	2000-2002		2000-2001		2001-2002	
	Coefficient	prob.	Coefficient	prob.	Coefficient	prob.
<i>RIND</i> (-1)	0.11	0.01	0.11	0.07	0.11	0.09

As we can see, the coefficients are all significant, though only at the 10 per cent level for 2000/01 and 2001/02. So, in order to check for seasonality we should also include the lagged index return.

The regression equation to be estimated is:

$$RIND_t = a + b_1TUE + b_2WED + b_3THU + b_4FRI + b_5RIND_{t-1} + e_t$$

The hypothesis to be tested is the following:

H_0 : $b_1 = b_2 = b_3 = b_4 = b_5 = 0$ and there is no day-of-the-week effect

H_1 : $b_i \neq 0$, for any i , which implies that there is a day-of-the-week effect

The estimated regression equations are shown in Table 6.10.

Table 6.10: Day-of-the-week regression results

Dependent Variable: RIND	2000-2002		2000-2001		2001-2002	
	Coefficient	prob.	Coefficient	prob.	Coefficient	prob.
Method: OLS						
C	-0.0014	0.34	-0.0033	0.21	0.0003	0.83
TUE	-0.0025	0.26	-0.0031	0.41	-0.0020	0.42
WED	-0.0006	0.79	-0.0012	0.75	-0.0001	0.96
THU	0.0011	0.54	0.0051	0.18	-0.0024	0.34
FRI	0.0019	0.39	0.0058	0.12	-0.0019	0.42
RIND(-1)	0.1000	0.02	0.093	0.14	0.1050	0.11

None of the dummies' estimated coefficients are significantly different from zero, so we conclude that the FTSE/ASE 20 index returns do not exhibit day-of-the-week effects in either year or in the two-year period.

In addition to the regression analysis, we performed an F-test on the average daily returns in order to check whether they differ significantly. The results are shown in Table 6.11.

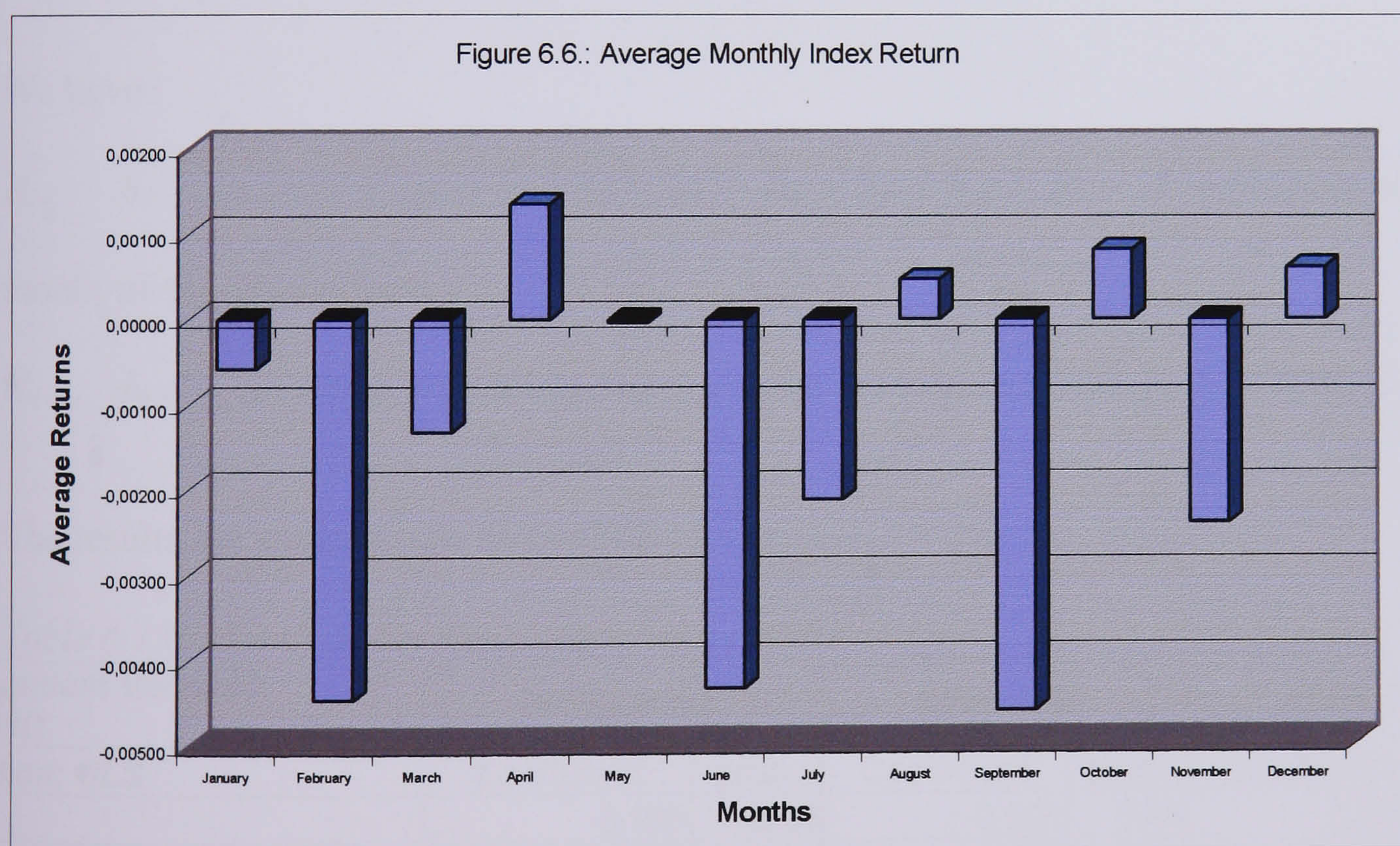
Table 6.11: Day-of-the-week F-statistic results

	2000-2002		2000-2001		2001-2002	
	F-statistic	prob.	F-statistic	prob.	F-statistic	prob.
Average daily returns	1.20	0.31	2.17	0.07	0.37	0.82

The F-statistics are not significant which means that the average daily returns do not differ significantly, i.e. there does not seem to be any day-of-the-week effect.

Month-of-the-year effect

An examination of Figure 6.6 shows that almost every fourth month there is a positive average return. The only exception is October where there are positive returns as well.



In order to check for month-of-the-year effects, we first test whether there is any effect on the monthly returns from the lagged monthly returns.

$MRIND_t = a_0 MRIND_{t-1} + e_t$, where $MRIND_t$, $MRIND_{t-1}$ are the index monthly returns at time t and $t-1$ respectively.

The results are shown in Table 6.12.

Table 6.12: MRIND regression results

Dependent Variable: MRIND	2000-2002		2000-2001		2001-2002	
	Coefficient	prob.	Coefficient	prob.	Coefficient	prob.
MRIND(-1)	-0.099	0.66	-0.017	0.96	-0.20	0.55

As we can see, the lagged return is insignificant, so the index monthly returns are not affected by the lagged return. Therefore, in order to check for month-of-the-year effects, we include only the dummy variables, as the lagged return is not significant.

The regression equation to be estimated is:

$$MRIND_t = a_0 + b_1FEB + b_2MAR + b_3APR + b_4MAY + b_5JUN + b_6JUL + b_7AUG + b_8SEP + b_9OCT + b_{10}NOV + b_{11}DEC + e_t$$

We have:

H_0 : $b_1 = b_2 = b_3 = b_4 = b_5 = b_6 = b_7 = b_8 = b_9 = b_{10} = b_{11} = 0$, and there are no month-of-the-year effects

H_1 : $b_i \neq 0$, for any i , which implies that there are month-of-the-year effects.

The results are summarised in Table 6.13.

Table 6.13: Month-of-the-year regression results

Dependent Variable: MRIND	2000-2002		2000-2001		2001-2002	
	Coefficient	prob.	Coefficient	prob.	Coefficient	prob.
C	-0.001	0.85	-0.001	0.94	-0.0003	0.85
FEB	-0.004	0.39	-0.002	0.88	-0.005	0.21
MAR	-0.001	0.87	0.000	0.99	-0.001	0.62
APR	0.002	0.67	0.006	0.70	-0.002	0.42
MAY	0.001	0.90	-0.002	0.91	0.003	0.36
JUN	-0.004	0.41	-0.006	0.72	-0.002	0.51
JUL	-0.002	0.73	0.000	0.99	-0.003	0.35
AUG	0.001	0.82	0.002	0.92	0.001	0.82
SEP	-0.005	0.19	-0.004	0.78	-0.009	0.10
OCT	0.001	0.76	-0.002	0.88	0.005	0.22
NOV	-0.002	0.68	-0.007	0.67	0.003	0.32
DEC	0.001	0.79	0.004	0.81	-0.001	0.59

None of the coefficients are significant, so none of the monthly returns have a significant impact on the index returns. This conclusion applies not only for the two-year period, but also for each individual year.

Next, we use an F-test to check for a significant difference between the monthly average returns. The results are shown in Table 6.14.

Table 6.14.: Month-of-the-year F-statistic results

	2000-2002		2000-2001		2001-2002	
	F-statistic	prob.	F-statistic	prob.	F-statistic	prob.
Average monthly returns	0.69	0.72	0.19	0.95	13.18	0.21

The F-statistic is not significant, which means that the index does not show any evidence of month-of-the-year effects. The same results can be drawn from the regression analysis between the index returns and dummy variables for the twelve months.

Overall, we can conclude that the FTSE/ASE 20 index does not show any evidence of calendar effects.

6.2.4. Conclusion from the ASE's efficiency tests

Having interpreted all of our tests, we are in a position to argue with a certain degree of confidence that, based on the whole sample, the ASE is not an efficient market. This was the expected result as the ASE is seen as an emerging market. All of the tests (apart from the seasonality test) lead us to the above conclusion. In particular, the most important tests (the random walk test, the test for asymmetric information and the volatility tests) provide strong evidence that the ASE is inefficient over the two-year period.

Based on the efficiency tests on the two years individually, we can argue that the ASE is not strong or semi-strong form efficient in either of the two years. However, with regard to asymmetric information, we do observe some improvement in efficiency, as there is less evidence of asymmetric information in 2001/02. With regard to volatility, there is no evidence of a structural change between the two years of the study. However, there is higher correlation between TV and IMV in 2001/02 compared to 2000/01. Also, despite the fact that there is evidence of volatility clustering in both years, ARCH effects are not significant in 2001/02.

Finally, the weak form efficiency tests imply that the ASE is an inefficient market in 2000/01, as all tests support this view. However, in 2001/02, the random walk and runs tests support the view that the ASE has become a weak form efficient market.

Overall, our results do seem to indicate some improvement in the efficiency level of the ASE from 2000/01 to 2001/02, and that the market could be regarded as weak-form efficient for the year 2001/02.

6.3. ASE normality tests

This group of tests are designed to analyse the ASE and the behaviour of the FTSE/ASE 20 index. The reason for testing the index is the need to understand whether the Greek Stock Market, and more specifically the FTSE/ASE 20 index, is a suitable market for normal-theory models like the BSOPM. The tests that will follow are normality tests. The tests have been conducted for the two years of the study and for each year individually. The reason for testing the two years individually is that we want to examine whether there is any change in normality between the two years.

6.3.1. Jarque-Bera normality tests

The Jarque-Bera (JB) tests for normality are applied to changes in the log-prices and the actual prices of the FTSE/ASE 20 index, first for the full set of observation, then for continuous trading days and finally for two days' break trading.

(a) Testing the total set of observations (sample size for both years = 500, sample size for each year = 250):

The hypotheses to be tested are:

H_0 : Changes in the prices of the index are normally distributed

H_1 : Changes in the prices of the index are not normally distributed

H_0 : Changes in the log-prices of the index are normally distributed

H_1 : Changes in the log-prices of the index are not normally distributed

The JB statistic follows a chi-squared distribution with 2 degrees of freedom so the critical value at the 5% level of significance is 5.99. So, if the JB value < 5.99, we cannot reject the normality assumption, but if the JB value > 5.99, then we can reject H_0 . The results are summarised in table 6.15.

Table 6.15: JB statistic for total set of observations

	2000-2002	2000-2001	2001-2002
Index change	299.19*	50.75*	36.35*
Log-index change	193.64*	61.08*	23.89*
*significant at 5% level			

In Figures 6.7 and 6.8, we are able to see the histogram for the changes of the index prices and the log-index prices, respectively (see also Appendix 9).

Figure 6.7: Change of the index prices – histogram and descriptive statistics

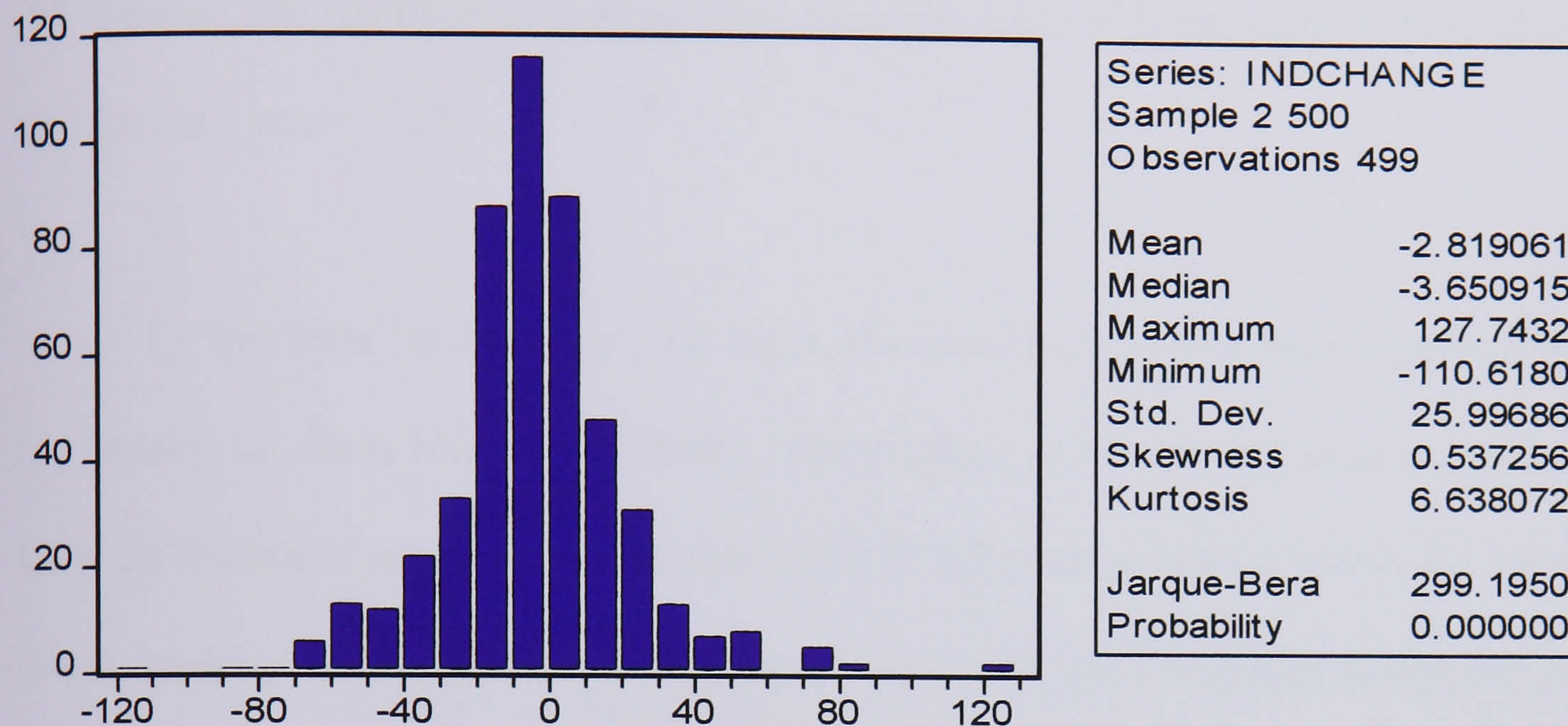
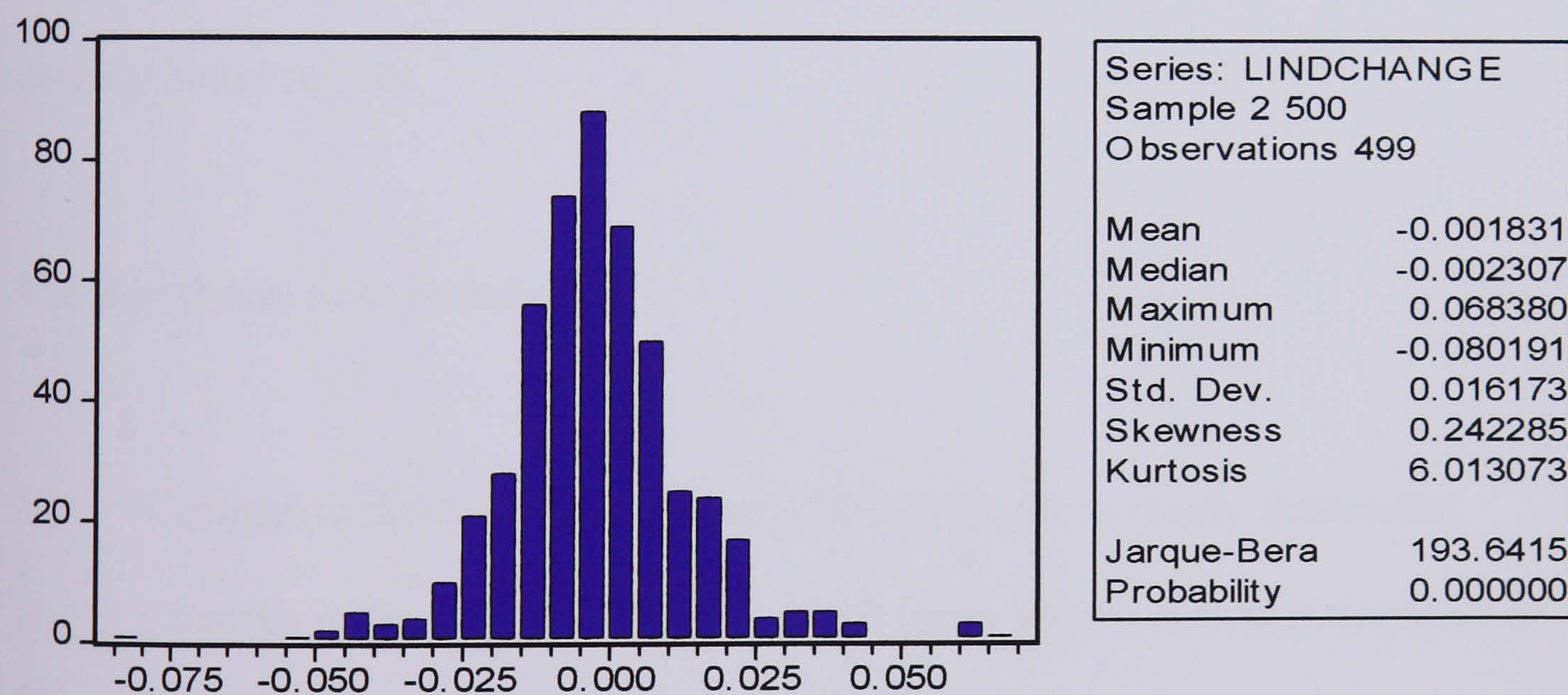


Figure 6.8: Change of the log-index prices – histogram and descriptive statistics



The JB value for the index prices for the two years together is 299.19, which is highly significant at the 5% level. This is an indication that we can reject the null hypothesis and conclude that the index is not normally distributed. The same conclusion can be drawn from the JB values on each of the two years. So, according to the JB values, there was no significant change in the normality of the index prices between 2000/01 and 2001/02.

Furthermore the log-index prices appear to be non-normal, as the JB values for the two years together and for each individual year are highly significant.

(b) Testing the continuous trading days (sample size for both years = 394, sample size for each year = 197)

By the term 'continuous', we mean the daily trading that takes place without any breaks, i.e. from Monday to Friday. The purpose of performing such a test is that from the literature we can observe that there is information which enters the market during trading breaks, which can only be incorporated into the prices during the next session. This could create anomalies such as day-of-the-week or end-of-the-week effects. By testing the market without this discontinuous trading we should be able to develop better results.

The hypotheses to be tested are:

H_0 : Changes in the continuous prices of the index are normally distributed

H_1 : Changes in the continuous prices of the index are not normally distributed

H_0 : Changes in the continuous log-prices of the index are normally distributed

H_1 : Changes in the continuous log-prices of the index are not normally distributed

The results are summarised in Table 6.16. This time the JB value is 309.05, so we are able to reject the null hypothesis and to conclude that the index's returns are not normally distributed.

Again, the JB value for continuous log-index change is highly significant (230.99) at the 5% level, compared to the critical value 5.99. It is also significant in each individual year. This is another indication that allows us to reject the normality assumption of the index. This result also suggests, therefore, that the market may be characterised as inefficient.

Table 6.16: JB statistic for continuous trading

	2000-2002	2000-2001	2001-2002
Continuous index change	309,05*	45,79*	55,91*
Continuous log-index change	230,99*	48,3*	38,66*
*significant at 5% level			

Figures 6.9 and 6.10 show the histograms and the descriptive statistics for continuous trading for the two-year period (see also Appendix 9).

Figure 6.9: Change in the continuous index prices – histogram and descriptive statistics

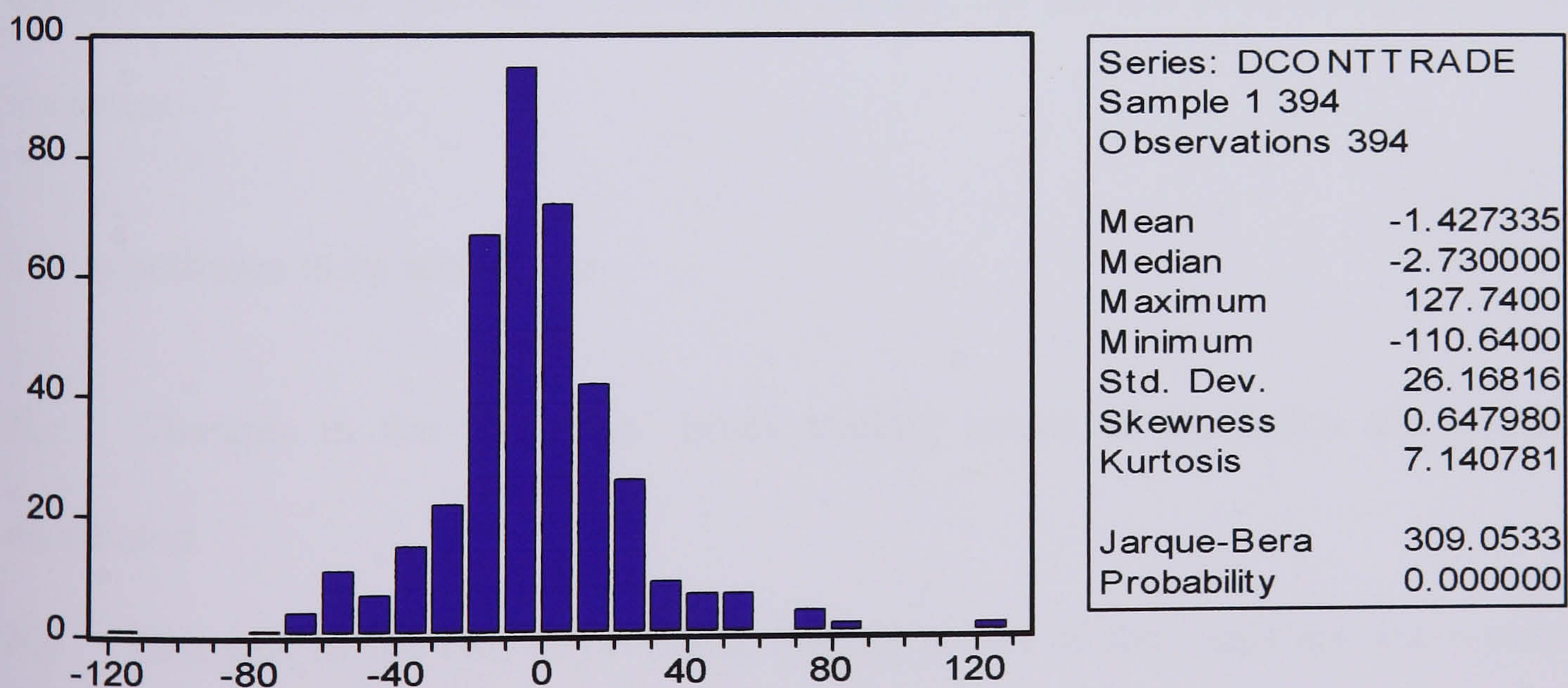
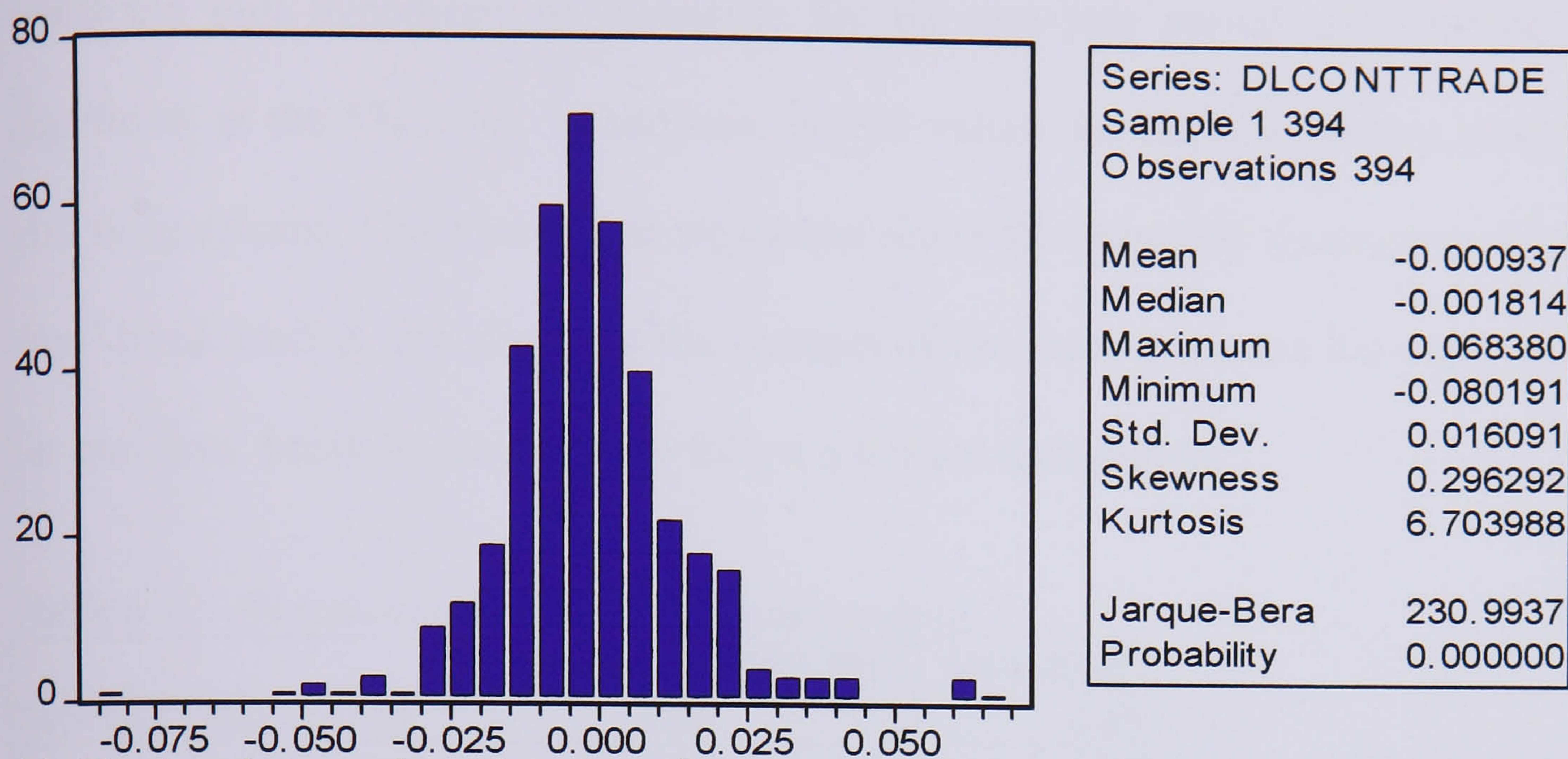


Figure 6.10: Change of the continuous log-index prices – histogram and descriptive statistics



(c) Testing the two days' break trading (sample size for both years = 106, sample size for each year = 53)

By the term 'two days' break' trading we mean the trading that takes place between discontinuous days i.e. Friday to Monday. By testing the two days' break trading, we can produce results as to the normality of the market, bearing in mind that during the weekend information enters the market, but has not been incorporated into the prices.

The hypotheses to be tested are:

H_0 : Changes in the two days' break trading prices of the index are normally distributed.

H_1 : Changes in the two days' break trading prices of the index are not normally distributed.

H_0 : Changes in the two-days' break trading log-prices of the index are normally distributed.

H_1 : Changes in the two days' break trading log-prices of the index are not normally distributed.

The JB statistics of 5.04 and 1.46 shown in Table 6.17 do not allow us to reject the null hypothesis of normality for the two-year period, as they are not significant at the 5% level. In addition, the JB values for each of the two years are also insignificant. This means that we cannot reject the normality assumption for two days' break trading, meaning that the changes of the index price and log-index prices for two days' break trading seem to follow a normal distribution.

Table 6.17: JB statistic for two-days break trading

	2000-2002	2000-2001	2001-2002
Two-days index change	5.04	1.12	0,85
Two-days log-index change	1.46	2.1	0.5

Figures 6.11 and 6.12 show the histograms for these two cases (see also Appendix 9).

Figure 6.11: Change in the two-days break index prices – histogram and descriptive statistics

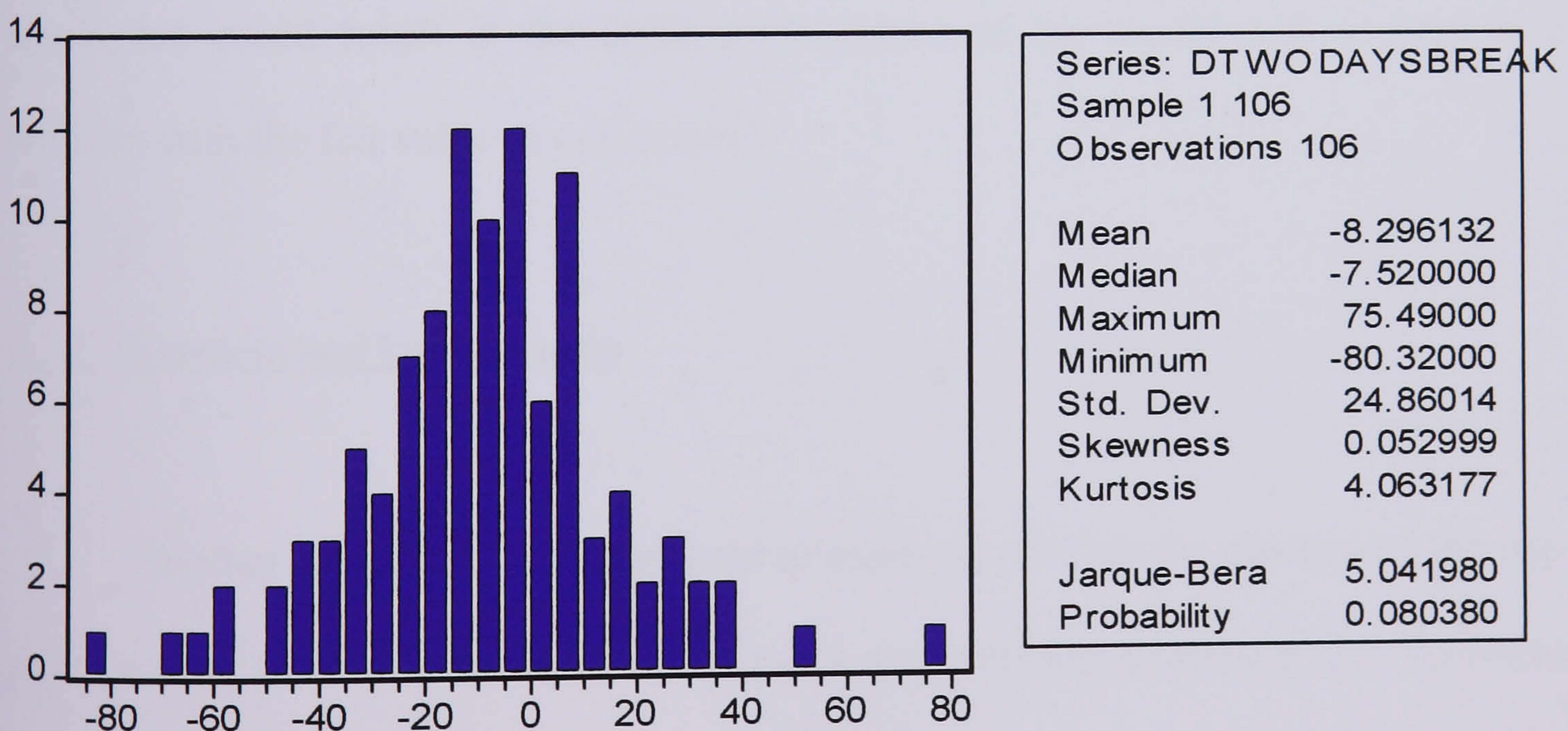
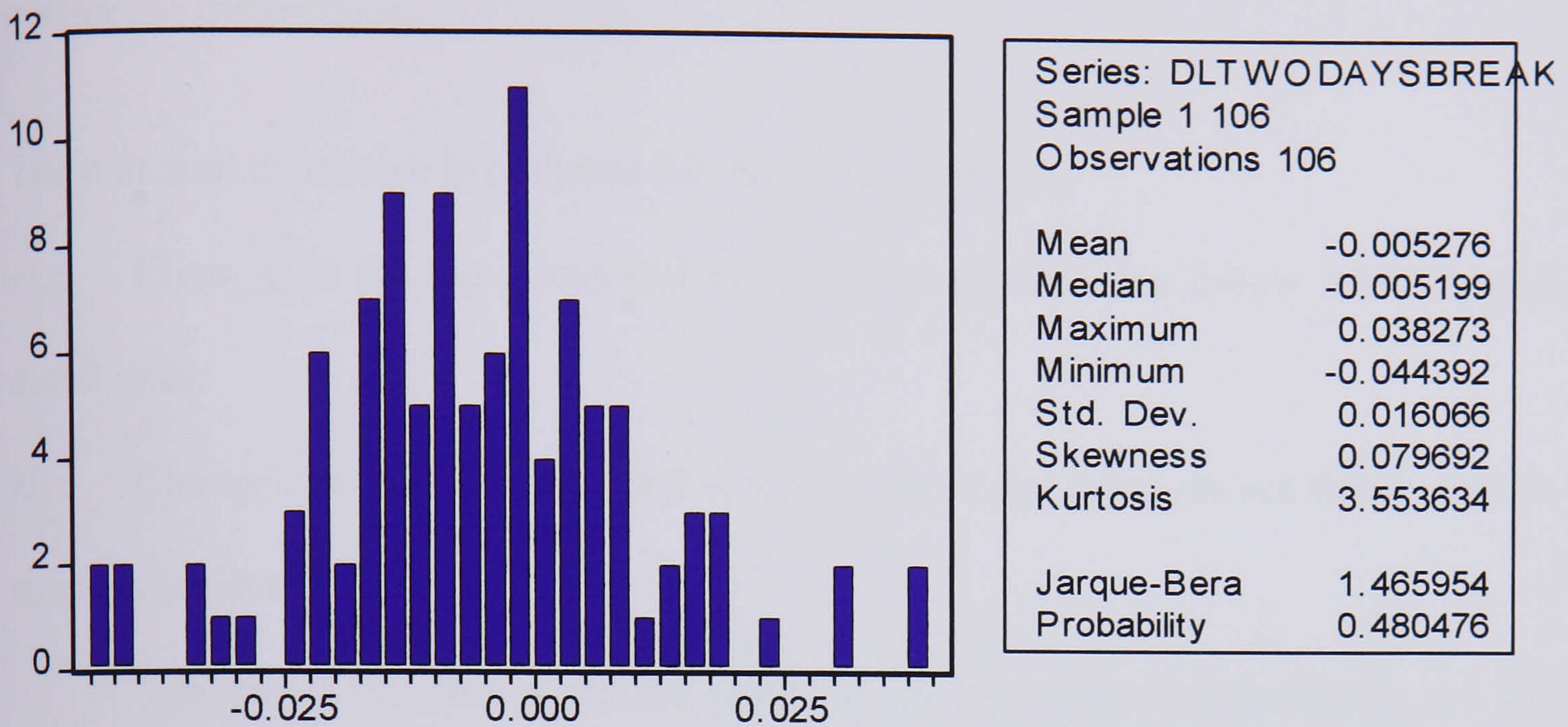


Figure 6.12: Change in the two-days break log-index prices – histogram and descriptive statistics



Summarising all the above tests, we can conclude with a reasonable amount of certainty that the changes in the log-prices and the actual prices of the FTSE/ASE 20 index are not normally distributed (except for two days' break trading). This is evidence that one of the important assumptions of the BSOPM is not satisfied. This conclusion could result in the under-performance of the model and so lead to a problem with the fair value of call options.

6.3.2. Skewness and kurtosis tests

Another set of tests that may help to examine whether the changes in the log-prices and in the actual changes of the index are normally distributed are skewness and kurtosis tests. We choose to perform such tests, as they may provide more precise conclusions as to factors that cause the non-normality (skewness, kurtosis or both).

The null and alternative hypotheses for the skewness test are:

H_0 : Changes in the log-prices and actual prices of the index follow a symmetric distribution

H_1 : Changes in the log-prices and actual prices of the index do not follow a symmetric distribution

The null and alternative hypotheses for the kurtosis test are:

H_0 : Changes in the log-prices and actual prices of the index follow a bell-shaped distribution

H_1 : Changes in the log-prices and actual prices of the index do not follow a bell-shaped distribution

The above hypotheses are the same for all three sets of observations, i.e. for the total set, for the continuous trading set and for the two-days' break trading set.

Tables 6.18 and 6.19 summarise all skewness and kurtosis results for the two-year period and for each individual year.

Table 6.18: Skewness statistics

	2000-2002		2000-2001		2001-2002	
	skewness	t-statistic	skewness	t-statistic	skweness	t-statistic
Index change	0.53	4.85*	0.60	3.90*	0.25	1.62
Log-index change	0.24	2.19*	0.32	2.08*	0.13	0.84
Continuous index change	0.64	5.20*	0.63	3.64*	0.28	1.62
Continuous log-index change	0.29	2.35*	0.20	1.15	0.08	0.46
Two-days index change	0.05	0.21	0.38	1.16	0.02	0.06
Two-days log-index change	0.08	0.34	0.10	0.31	0.30	0.92

*significant at 5% level

Table 6.19: Kurtosis statistics

	2000-2002		2000-2001		2001-2002	
	kurtosis	t-statistic	kurtosis	t-statistic	kurtosis	t-statistic
Index change	6.63	30.41*	4.85	15.81*	4.80	15.64*
Log-index change	6.01	27.56*	5.33	17.37*	4.49	14.63*
Continuous index change	7.14	29.11*	4.99	14.47*	5.54	16.07*
Continuous log-index change	6.70	27.31*	5.39	15.64*	5.16	14.97*
Two-days index change	4.06	8.72*	3.66	5.68*	2.76	4.28*
Two-days log-index change	3.55	7.63*	3.68	5.71*	2.89	4.48*

*significant at 5% level

Comparing our values with the critical values of the t-distribution, we can see that the t-statistics for both kurtosis and skewness allow us to reject both null hypotheses and so reject the normality assumption at the 5% level of significance. As can be seen, the total set of data appears to be negatively skewed and leptokurtic. The same conclusion can be reached for each of the two years. Based on these results we can conclude that the changes in the actual and log-prices of the index are not normally distributed.

The continuous trading days series appear to be negatively skewed and leptokurtic over the two-year period, as the t-statistic for skewness and kurtosis are positive and significant at the 5% level. So the null hypotheses of a bell-shaped and symmetric distribution can be rejected for both the actual and log-prices. Examining the two individual years, we see that the price changes are leptokurtic but not skewed.

With regard to the two days' break trading series, the changes in index prices and index log-prices appear to be symmetrically distributed, for the two-year period and for each individual year, as neither of the null hypotheses can be rejected. However, there is evidence that the series are leptokurtic, as the t-statistics for kurtosis are all significant at the 5% level.

Overall, we can argue that the ASE is not normally distributed, as there is evidence of asymmetry and kurtosis. In addition, we are able to observe that there are no significant changes in the index's normality between 2000/01 and 2001/2002.

In summary, even though the two days' break trading series seems to be symmetrically distributed, we can reject the hypothesis that, overall, the changes of the actual and log-prices of the index are normally distributed. Hence, based on the above tests, we can conclude that a major assumption of the BSOPM does not hold.

6.4. Put-call parity tests

The second group of tests that will be analysed concern put–call parity. By testing put–call parity we will be able to draw conclusions as to the efficiency of the Greek Derivatives Market (ADEX). This is a very important test as so far we have concluded that the ASE is an inefficient market, which creates problems for the performance of the BSOPM. Testing the efficiency of the derivatives market will provide us with further evidence concerning the appropriateness of the model in inefficient markets.

A put–call parity model shows the relationship between the price of a put and the price of a call on the same underlying asset with the same expiration date, which prevents arbitrage opportunities (Stoll, 1969).

$$C + Xe^{-rt} = P + S$$

where:

C = the call premium

X = the call option's strike price

P = the put premium

S = the spot price of the Index

e = the exponential factor

r = risk free rate

t = time to expiration of the options

The significance of put-call parity is that it shows the arbitrage relationship. If parity does not hold for any reason between the two sides of the parity equation, this

should trigger arbitrage. However, the arbitrageurs must take into account transaction costs and liquidity in order to judge correctly whether arbitrage profits are possible.

In this section, we try to test whether there are any arbitrage opportunities in the ADEX market with and without transaction costs. These are very important tests because, as we said at the beginning of this section, the put-call parity test will allow us to examine if the ADEX market is inefficient or not (according to whether there are arbitrage opportunities or not).

The put-call parity equation (including the dividend yield) is as follows:

$$C + Xe^{-rt} = P + Se^{-qt}$$

where:

q = the dividend yield of the index.

However, there is also the put-call parity equation which includes the future price of the index:

$$C + Xe^{-rt} = P + F$$

In this equation, F is the future price of the index instead of the spot price. For this reason there is no dividend yield as the yield has been incorporated in the future price.

The tests presented below are divided into two parts. The first part is without the incorporation of transaction costs and there are two tests, one for the spot and one for the future price of the index. The second part also contains the tests for the spot and the future price of the index, and additionally incorporates transaction costs. Transaction costs are measured for the call and put options at €6 each multiplied by the premium and for the index at 0.2% of the index level (source: ADEX). In addition,

the tests will be performed for the two years of the study together and for each year individually.

The put-call parity equations including transaction costs are:

$$C + Xe^{-rt} - (P + Se^{-qt}) - T_c - T_p - T_{in} = 0$$

$$C + Xe^{-rt} - (P + F) - T_c - T_p - T_{in} = 0$$

where:

T_c = transaction costs for the call option

T_p = transaction costs for the put option

T_{in} = transaction costs for the index.

6.4.1. Testing put-call parity without transaction costs

In this section, we run a Wilcoxon signed rank test for the difference between paired observations i.e. the two parts of the put-call parity. The test will be performed based on the spot prices of the index and on the future prices of the index.

$$H_0: C + Xe^{-rt} = P + F$$

$$H_1: C + Xe^{-rt} \neq P + F$$

$$H_0: C + Xe^{-rt} = P + Se^{-qt}$$

$$H_1: C + Xe^{-rt} \neq P + Se^{-qt}$$

Table 6.20 reports the results.

Table 6.20: Wilcoxon signed rank test results - Put-Call parity

	2000-2002		2000-2001		2001-2002	
	W-statistic	prob.	W-statistic	prob.	W-statistic	prob.
spot price	48560	1.36E-05	5448	3.86E-19	10786	1.85E-05
future price	54972	0.017	8192	5.88E-11	11231	9.89E-05

All Wilcoxon W-statistics are significant at the 5% level of significance. So we can reject both the null hypotheses as the two parts of the put-call parity are

significantly different. This conclusion applies not only for the two years together but also for each of the two individual years. Furthermore we can observe that there is no change between the two years of the study as for each year the W-statistics are significant. Based on these results we can see that parity does not hold, as there is a significant difference between the values of the two sides. The conclusion from this test is that the market gives rise to arbitrage opportunities, which is a sign of inefficiency. However, it would be more reasonable to see whether these arbitrage opportunities still hold when we incorporate transaction costs.

6.4.2. Testing put-call parity with transaction costs

As we have seen, there are four variations of the put-call parity. The difference between the first two and the second two variations is that the first group has been calculated with the spot price of the index, while the second group is based on the futures price of the index. However, there is another difference. We performed not just a put–call parity test but also a call–put parity test. We can justify this choice by arguing that if we want to test whether there are arbitrage opportunities in the ADEX we have to test it from both sides, i.e. from the side of the put and from the side of the call.

The most important test for examining whether there are any arbitrage opportunities in the market is the t-test on the parities and the hypotheses to be tested are as follows:

$$H_0: (C + Xe^{-rt}) - (P + Se^{-qt}) - T_c - T_p - T_{in} = 0$$

$$H_1: (C + Xe^{-rt}) - (P + Se^{-qt}) - T_c - T_p - T_{in} > 0$$

$$H_0: (P + Se^{-qt}) - (C + Xe^{-rt}) - T_c - T_p - T_{in} = 0$$

$$H_1: (P + Se^{-qt}) - (C + Xe^{-rt}) - T_c - T_p - T_{in} > 0$$

$$H_0: (C + Xe^{-rt}) - (P + F) - T_c - T_p - T_{in} = 0$$

$$H_1: (C + Xe^{-rt}) - (P + F) - T_c - T_p - T_{in} > 0$$

$$H_0: (P + F) - (C + Xe^{-rt}) - T_c - T_p - T_{in} = 0$$

$$H_1: (P + F) - (C + Xe^{-rt}) - T_c - T_p - T_{in} > 0$$

If $t < 1.645$, then accept null hypothesis

if $t > 1.645$, then reject null hypothesis

Table 6.21 shows the results for the put-call parity tests when transaction costs are incorporated.

Table 6.21: T-statistic results - Put-Call parity

	2000-2002	2000-2001	2001-2002
Put-call based on spot prices of the index	-7,36	-12,02	2,32*
Call-put based on spot prices of the index	2,25*	8,44*	-7,02
Put-call based on future prices of the index	-5,50	-9,06	1,81*
Call-put based on future prices of the index	-0,49	4,92*	-6,80
*significant at 5% level			

The main aim of this test is to identify whether there are any significant arbitrage opportunities in the ADEX market. We tested the four parities and the results were the expected ones. Almost all the put-call parities (with spot and future prices) showed that there are no arbitrage opportunities in the market when transaction costs are incorporated into the parity. The only exception is the call-put parity based on the spot prices of the index.

With regard to the two individual years, there is evidence that the put-call parities seem to hold more in 2001/02, whereas the call-put parities show the opposite results i.e. that the parities hold only in 2000/01.

However, based on the whole set of data, the ADEX market seems to be efficient as we observe arbitrage opportunities only in the call-put parity based on the spot price of the index. We could say that even this arbitrage opportunity may be a result of the overvaluation/undervaluation of option contracts, which was observed earlier. So, with some degree of certainty we can argue that the ADEX market is an efficient market, as there are no arbitrage opportunities.

6.5. BSOPM's validity tests

The final part of the tests in this chapter includes tests of the BSOPM. For the purpose of this study, we use in our tests the BSOPM with future prices instead of spot prices, with the benefit that future prices do not need to be discounted with the dividend yield and the model does not use expiration dates.

Finally, we use two different volatilities (implied and actual) in order to be able to observe any significant differences in the BSOPM value. Our tests for ASE efficiency lead us to conduct such a test, because the results that we have already analysed show that implied volatility is not a good predictor of the actual volatility of the market. The complete formulas of the BSOPM variations can be found in Chapter 3.

By testing the BSOPM we will try to produce significant conclusions regarding the validity of the model in emerging markets or whether emerging markets cause the formula to under-perform.

In order to conduct the test for the validity of the BSOPM in emerging markets we employ the Wilcoxon Signed Rank test on the differences between the call option market prices and the BSOPM's variations theoretical prices. The same method is

employed in order to test for any significant difference between the put and call implied volatilities.

The variables to be tested are as follows:

COP = call option price from the market (ADEX)

C_1 = option price calculated from the BSOPM with implied volatility and based on the spot value of the index

C_2 = option price calculated from the BSOPM with true volatility and based on the spot value of the index

C_3 = option price calculated from the BSOPM with implied volatility and futures prices of the index

C_4 = option price calculated from the BSOPM with true volatility and futures prices of the index.

CALLIMV = implied volatility of the at-the-money call options with two month to expiration and the FTSE/ASE 20 as the underlying index

PUTIMV = implied volatility of the at-the-money put options with two month to expiration and the FTSE/ASE 20 as the underlying index

6.5.1. Wilcoxon signed rank test on the BSOPM variations and the call market prices

Here the hypotheses to be tested are:

$$H_0: \overline{COP} = \overline{C}_i$$

$$H_1: \overline{COP} \neq \overline{C}_i$$

where i is the variation of the BSOPM theoretical call option price. Table 6.22 summarises the results of the Wilcoxon statistic.

Table 6.22: Wilcoxon signed rank test results - BSOPM

	2000-2002		2000-2001		2001-2002	
	W-statistic	prob.	W-statistic	prob.	W-statistic	prob.
C1 - COP	48532	1.3E-05	4330	3.56E-23	6722	4.89E-15
C2 - COP	16658	0.00	1955	0.00	6713	4.6E-15
C3 - COP	24284	0.00	4543	2.24E-22	7126	7.59E-14
C4 - COP	45668	1.56E-07	14395	0.26	4110	5.12E-24

Performing a Wilcoxon Signed Rank test, we have examined whether the market price was significantly different from the BSOPM price. The results show that we can reject the null hypothesis at the 1% level of significance (or lower) and so conclude that the means of the two samples are not equal. The only exception is C₄ with COP in 2000/01, where the two variables are not significantly different. However, on the same pair in 2001/02, the difference becomes significant.

The above results could be interpreted as inefficiency. The reason for stating this is that the theory says that the market price and the BSOPM price should be the same or should not be significantly different, otherwise the market is inefficient or the model is not operating properly. If either of these is the reason, the conclusion that could be made is that the model is not appropriate for emerging markets.

6.5.2. Test on the difference between the put and call implied volatilities

BSOPM assumes that put and call options should have the same implied volatility if they are identical i.e. if they have the same expiration dates, underlying asset and strike prices. In order to test for equal implied volatilities we will perform a Wilcoxon Signed Rank test on the two implied volatilities for the at-the-money call and put options, with two months to expiration, on the FTSE/ASE 20 index.

We have:

$$H_0: \overline{CALLIMV} = \overline{PUTIMV}$$

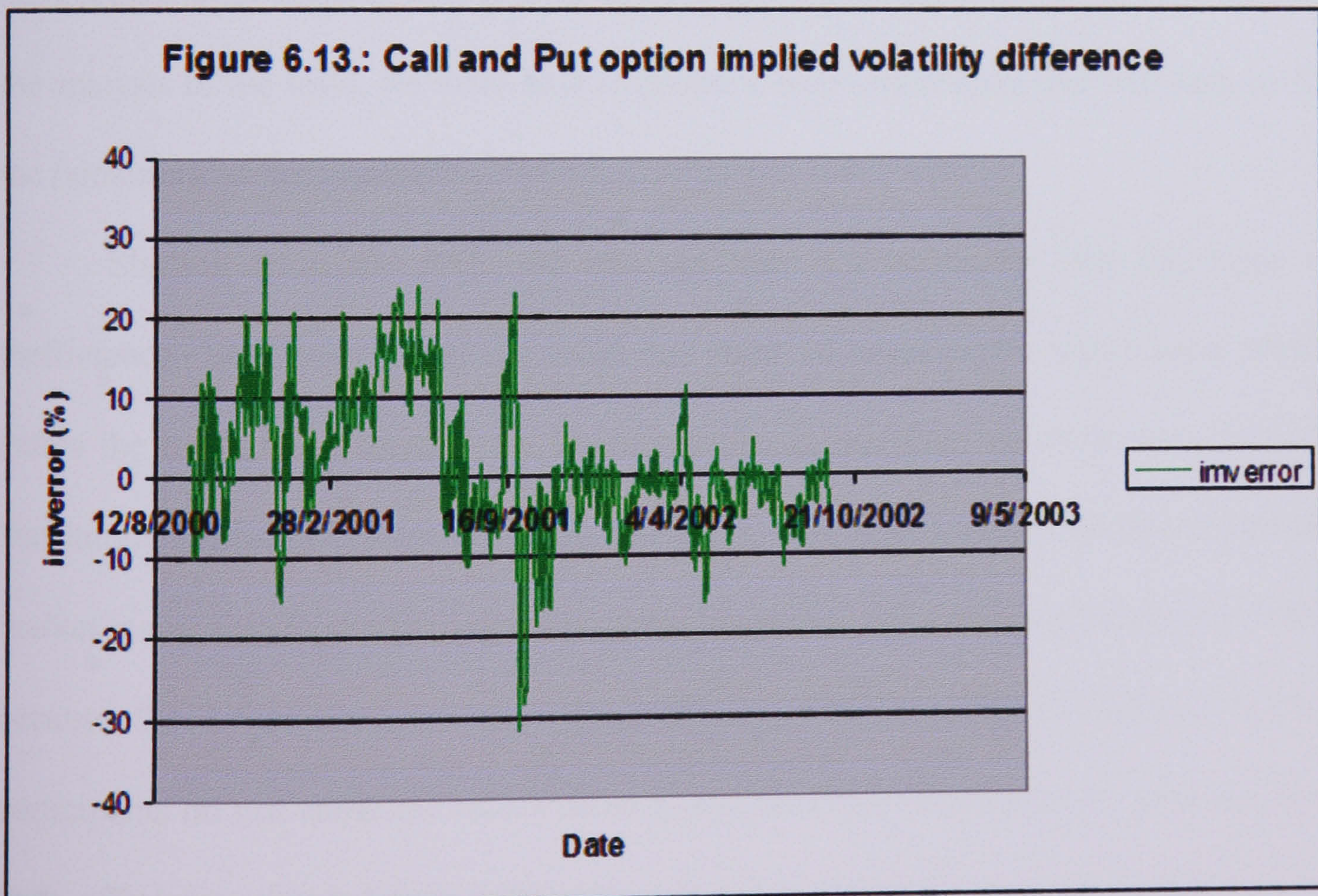
$$H_1: \overline{CALLIMV} \neq \overline{PUTIMV}$$

The results are shown in Table 6.23.

Table 6.23: Wilcoxon signed rank test results – Call vs Put implied volatility

	2000-2002		2000-2001		2001-2002	
	W-statistic	prob.	W-statistic	prob.	W-statistic	prob.
callimv vs putimv	52106	0.00	4563.5	3E-22	6447	7.05E-16

The difference between the two volatilities is significant, not only for the whole set of data but also for the two individual years. This can also be observed in Figure 6.13. The *imverror* is the difference between the call and put implied volatilities (see Appendix 10).



From Figure 6.13, we are able to observe that throughout the first half of the period the average call implied volatility is higher than the put and the reverse is observed for the second half of the period. This is an indication that put-call parity

does not hold. The significant difference between the call and put implied volatilities helps to explain the arbitrage opportunities that were observed in the put-call parity section without transaction costs. This significant difference between the implied volatilities is another indication that the BSOPM is not valid.

6.6. Conclusion

This thesis has two main objectives: to test whether the ADEX and ASE markets are inefficient and if they are, to test whether the BSOPM is an appropriate model for option pricing in such markets. To examine the efficiency of the ASE and ADEX markets and the BSOPM, we employed various tests including volatility tests, market efficiency tests, option pricing efficiency tests and put-call parity tests. During the analysis of the tests, we were able to produce some arguments that will help us for the remaining of the research.

Starting from the ASE, we can say that it is a market that has signs of inefficiency. We showed that the ASE has signs of asymmetric information which enters the market and distorts the index returns. In addition, volatility tests showed that implied volatility is not correctly estimated. The interpretation of this is that the market is not able to predict volatility, meaning that is not operating efficiently either because the information entering the market is not complete or because market participants do not value the information in the best way. Furthermore, tests on weak form efficiency showed that there are signs of predictability in the market and by using technical analysis, one could earn excess profits. However, the tests on the two years individually showed that there is some improvement in the efficiency level of

the ASE as in 2001/02 the market seems to be weak form efficient. However we still need to point out that the Chow Breakpoint test did not support this argument.

ASE shows non-normality in its returns as well. First, the returns of the actual and log-prices of the index are not normally distributed. The distribution seems to be leptokurtic and negatively skewed. Even the tests using continuous trading and two-days' break trading tend to support the view that index returns are not normally distributed. As has been said, normality is a very important assumption of the BSOPM in order for the model to produce fair option prices. The tests also showed that there was no change in normality between 2000/01 and 2001/02.

As the market is inefficient and non-normal, we can conclude that either the market creates problems for the fair pricing of options or the model is not appropriate for option pricing with such an underlying market.

The next test concerned the ADEX market. In order to test the ADEX market we employed a put-call parity test. The results from all the various tests based on parity concluded that parity does not hold. However, after the incorporation of transaction costs in the formula, the results showed that arbitrage opportunities disappear. The tests on the two individual years showed that for both years there are arbitrage opportunities without transaction costs. Once the transaction costs are incorporated, then it seems that there are some arbitrage opportunities from call-put parity in 2000/01 and from put-call parity in 2001/02. However, overall, the results show that once transaction costs are included, there are no arbitrage opportunities.

The final group of tests concerned the usefulness and validity of the BSOPM in inefficient markets. From the results, we can conclude that the BSOPM either has some difficulties in the pricing of options in the specific market (ADEX) or the market creates those difficulties to the model. Either way, option pricing seems to be

inefficient as the prices differ significantly from market prices. In addition, the call and put implied volatilities are significantly different, which is another indication that the BSOPM is not valid. Also, there is no change between 2000/01 and 2001/02, as in both years the BSOPM theoretical values differ significantly from COP and the two implied volatilities also differ significantly.

Finalising our analysis for the ASE, ADEX and BSOPM, we should say that most of the problems as to the fair pricing of options have been created by the underlying stock market, due to asymmetric information, the mis-prediction of volatility and the non-normal distribution of index price returns. As these inefficiencies do not allow the model to price an option at its fair price, we argue that some new variables should be added to the model to enable the model to perform better. In the first few chapters of this research, we concluded that inefficiencies like asymmetric information, insider trading, low transaction volumes, seasonality, etc. make the indices or share prices behave abnormally and as a consequence make the BSOPM less accurate. In the next chapter, we try to test the significance of such anomalies. Such tests will allow us to reach our goal and our final conclusion, which is whether the BSOPM needs to be changed for inefficient markets.

CHAPTER 7: Testing the significance of ASE's anomalies on option prices

7.1 Introduction

In Chapter 3, we discussed some of the problems associated with the BSOPM which are likely to create pricing inefficiencies in option contracts. In Chapter 4, we identified from the literature a number of market anomalies, in particular, asymmetric information, insider trading, seasonal effects and low market depth, that exist in mature and emerging markets, but which are likely to be much more severe in emerging markets. We concluded that the consequence of these anomalies is to create inefficient markets.

In Chapter 6, we conducted a battery of tests designed to assess the efficiency of the ASE and ADEX. The results of these tests provide us with evidence that the ASE is inefficient, as expected, but that the ADEX is efficient in the sense that there are no arbitrage opportunities in the market.

To summarise, we have the following conclusions so far:

- The BSOPM may not be an appropriate model for emerging markets because of the existence of market anomalies and the assumptions concerning implied volatility and the normality of the underlying asset.
- The ASE is inefficient as there is evidence of asymmetric information/insider trading. There is also evidence of inefficiency from the random walk test and

test of independence. In addition, we have found evidence of a significant difference between true and implied volatility and evidence of ARCH effects. However, we have found no significant evidence of seasonal effects.

- The ADEX is efficient in the sense that there are no arbitrage opportunities, but it seems that option contracts may be overpriced/underpriced because of the anomalies of asymmetric information and insider trading which prevent the ASE from correctly predicting volatility. The option contract mispricing may be due to the anomalies that were identified and/or to the inefficient status of the ASE

In this chapter, we use econometric methods to investigate the significance of asymmetric information/insider trading, transaction costs and volumes (market depth) and the mis-estimation of implied volatility, as influences on option prices.

7.2. Variables

To do this, we construct regression models, using the following set of variables:

BSSPIMV = BSOPM theoretical prices which are calculated based on the *spot* index and *implied* volatility

BSSPTV = BSOPM theoretical prices which are calculated based on the *spot* index and *true* volatility

BSFPIMV = BSOPM theoretical prices which are calculated based on the *future* index and *implied* volatility

BSFPTV = BSOPM theoretical prices which are calculated based on the *future* index and *true* volatility

COP = market's call option prices

TCF = transaction costs for future prices

TCI = transaction costs for spot prices

OTV = option transaction volume

ITV = index's transaction volume

AI = asymmetric information (which consists of the dummy variables AIU, AIN, AID, as explained in Chapter 5).

Seasonality variables are not included as the calendar effect tests in Chapter 6 showed no evidence of seasonality in the ASE. A more detailed description of all the variables is contained in Chapter 5.

Having concluded the list of variables that will be used in the model, we first present some descriptive statistics, a correlation matrix and unit root tests for each variable. The purpose of the unit root tests is to identify whether the variables are integrated of the same order. The unit root study will enable us to conclude whether we should use standard regression or cointegration models. The test employed is the augmented Dickey-Fuller unit root test.

If the variables under examination are $I(1)$, then cointegration will be followed. If the variables are $I(0)$, then we will use a standard regression method. In the case where not all variables are $I(1)$ or $I(0)$, we will check the dependent variable and most important independent variables. If these specific variables are $I(1)$, then we will use cointegration, if they are $I(0)$, regression will be used. Having determined the final method, we will perform the analysis. The final step will be the various tests that

will be performed on the model and its residuals. These tests will include t-tests on the BSOPM coefficients, tests on the redundant variables, Chow Forecast tests, Chow Breakpoint test and Root Means Squared Error tests (RMSE).

7.2.1. Descriptive statistics

Table 7.1 summarises the descriptive statistics for the variables that are used in the regression analysis.

Table 7.1: Descriptive Statistics

	COP	BSFPIMV	BSFPTV	BSSPIMV	BSSPTV
Mean	52.76	58.83	47.77	51.12	42.54
Median	50.40	55.23	41.67	49.34	41.06
Maximum	171.00	180.46	127.97	128.73	90.59
Minimum	3.20	9.45	4.57	15.40	7.98
Std. Dev.	25.06	28.15	25.84	19.22	17.14
Skewness	0.65	0.71	0.66	0.61	0.36
Kurtosis	3.75	3.42	2.68	3.27	2.55
Jarque-Bera	47.53	46.50	38.43	33.23	15.39
Probability	0.00	0.00	0.00	0.00	0.00
Observations	500	500	500	500	500

	AID	AIU	TCF	TCI	OTV	ITV
Mean	0.02	0.02	15.09	15.06	105.19	4001667.
Median	0.00	0.00	14.93	14.93	35.00	3215530.
Maximum	1.00	1.00	16.82	16.74	1105.00	52544715
Minimum	0.00	0.00	13.85	13.88	1.00	890621.0
Std. Dev.	0.16	0.16	0.72	0.69	160.40	3913309.
Skewness	5.72	5.72	0.44	0.45	2.55	7.89
Kurtosis	33.74	33.74	2.13	2.21	10.89	82.95
Jarque-Bera	22418.96	22418.96	31.90	30.11	1843.03	138370.7
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	500	500	500	500	500	500

From the means and standard deviations, we see that there is a high degree of variability in all the variables. Also, there is a difference between the mean and median values of COP and the BSOPM variations. In other words, COP and all the

BSOPM variations seem to have non-normal distributions. Specifically, we can observe that the BSFPTV and the BSSPTV are platykurtic, whereas the BSFPIMV and BSSPIMV are leptokurtic. Transaction costs (TCF and TCI) and transaction volumes (OTV and ITV) are also non-normally distributed. For transaction costs, this was expected as they do not change rapidly and do not change many times within a year.

7.2.2. Correlation matrix

A correlation matrix is shown in Table 7.2. The correlation coefficients between the independent variables are tested in order to check for possible problems associated with multicollinearity.

Table 7.2: Correlation Matrix

	COP	BSFPIMV	BSFPTV	BSSPIMV	BSSPTV
COP	1.00	0.89	0.77	0.89	0.79
BSFPIMV	0.89	1.00	0.90	0.91	0.77
BSFPTV	0.77	0.90	1.00	0.72	0.64
BSSPIMV	0.89	0.91	0.72	1.00	0.87
BSSPTV	0.79	0.77	0.64	0.87	1.00
AID	-0.01	0.01	0.02	-0.01	0.01
AIU	0.10	0.09	0.08	0.06	0.01
TCF	0.71	0.77	0.79	0.61	0.65
TCI	0.71	0.76	0.78	0.61	0.66
OTV	-0.49	-0.50	-0.46	-0.48	-0.48
ITV	0.12	0.15	0.11	0.12	0.05

	AID	AIU	TCF	TCI	OTV	ITV
COP	-0.01	0.10	0.71	0.71	-0.49	0.12
BSFPIMV	0.01	0.09	0.77	0.76	-0.50	0.15
BSFPTV	0.02	0.08	0.79	0.78	-0.46	0.11
BSSPIMV	-0.01	0.06	0.61	0.61	-0.48	0.12
BSSPTV	0.01	0.00	0.65	0.66	-0.48	0.05
AID	1.00	-0.02	-0.02	-0.02	-0.08	0.07
AIU	-0.02	1.00	0.10	0.10	0.05	0.10
TCF	-0.02	0.10	1.00	0.99	-0.50	0.09
TCI	-0.02	0.10	0.99	1.00	-0.50	0.08
OTV	-0.08	0.05	-0.50	-0.50	1.00	-0.02
ITV	0.07	0.10	0.09	0.08	-0.02	1.00

The figures in bold and red highlight the high correlation figures that could cause multicollinearity. As can be seen, a high degree of correlation exists between all the BSOPM's variations and between total transaction costs based on the spot and future prices of the index. However, the BSOPM variations are used in different regression equations and so cannot cause multicollinearity. Additionally, TCF and TCI are also used in different regression equations, so we can conclude that the regression models are unlikely to suffer from problems of multicollinearity.

Further, we can comment on the correlation between COP and the independent variables. COP is positively correlated with all the BSOPM variations, as expected. In addition, COP is positively correlated with all the remaining variables apart from OTV and AID. However, COP seems to be any only weakly correlated with AID, AIU and ITV.

7.2.3. Unit root tests

As indicated above, the unit root test to be used here is the ADF test. The results are summarised in Table 7.3.

Table 7.3: Unit Root Statistics:

<i>Variable</i>	<i>ADF-statistic</i>
COP	-6.54**
BSSPIMV	-6.90**
BSSPTV	-6.09**
BSFPIMV	-6.26**
BSFPTV	-4.20**
TCI	-3.95*
TCF	-3.84*
OTV	-8.03**
ITV	-8.07**
AID	-5.30**
AIN	-5.89**
AIU	-5.52**

*Significant at 5% level

**Significant at 1% level

From the unit root tests, we are able to conclude that the variables are $I(0)$ as most of the coefficient estimates are significantly different from one at the 1% level and the remainder (TCI and TCF) are significantly different from one at the 5% level.

As all variables are $I(0)$, we are able to use standard regression techniques in order to perform our tests. Furthermore, the fact that all variables are integrated of the same order strengthens the validity of the model.

7.3. Regression analysis

As the independent variables include all the variations of the BSOPM and the two different volatilities (implied and true), four models are estimated. In each case, the dependent variable is the market option price (COP). The regression equations are set out in full below:

Model 1:

$$COP_t = a_0 + a_1BSFPTV_t + a_2TCF_t + a_3OTV_t + a_4AID_t + a_5AIU_t + u_{1t}$$

Model 2:

$$COP_t = b_0 + b_1BSSPTV_t + b_2TCI_t + b_3ITV_t + b_4OTV_t + b_5AID_t + b_6AIU_t + u_{2t}$$

Model 3:

$$COP_t = c_0 + c_1BSFPIMV_t + c_2TCF_t + c_3OTV_t + c_4AID_t + c_5AIU_t + u_{3t}$$

Model 4:

$$COP_t = d_0 + d_1BSSPIMV_t + d_2TCI_t + d_3ITV_t + d_4OTV_t + d_5AID_t + d_6AIU_t + u_{4t}$$

The hypotheses to be tested are:

$$H_0: a_0, a_2, a_3, a_4, a_5 = 0, a_1 = 1$$

$$H_1: a_1 \neq 1 \text{ and at least one of the other coefficient not equal to zero}$$

$$H_0: b_0, b_2, b_3, b_4, b_5, b_6 = 0, \quad b_1 = 1$$

$$H_1: b_1 \neq 1 \text{ and at least one of the other coefficient not equal to zero}$$

$$H_0: c_0, c_2, c_3, c_4, c_5 = 0, \quad c_1 = 1$$

$$H_1: c_1 \neq 1 \text{ and at least one of the other coefficient not equal to zero}$$

$$H_0: d_0, d_2, d_3, d_4, d_5, d_6 = 0, \quad d_1 = 1$$

$$H_1: d_1 \neq 1 \text{ and at least one of the other coefficient not equal to zero}$$

In each case, support for H_0 will suggest that asymmetric information/insider trading, transaction costs and volumes and the mis-estimation of implied volatility are all insignificant influences on option prices. Support for H_1 will suggest that at least one of these variables has a significant influence and that, therefore, the BSOPM is inadequate.

Having examined the regressions we gather together those that provide significant results and test their residuals and coefficients. Finally, we make comparisons between these regressions, the BSOPM option prices and the market option prices.

7.3.1. Models based on true volatility

7.3.1.1 Analysis of model 1

The results obtained from estimating model 1, using the method of OLS with White heteroscedasticity-consistent standard errors and covariances, are summarised in Table 7.4. The reason for using White's heteroscedasticity is that it can provide

correct estimates of the coefficient covariances in the presence of heteroscedasticity.

So it can still produce efficient coefficients despite the presence of heteroscedasticity.

Table 7.4: Model 1 – Results

Dependent variable: COP	Original Model		AR(1) included		No constant term		No insignificant variables	
	Coefficients	Prob.	Coefficients	Prob.	Coefficients	Prob.	Coefficients	Prob.
Method: OLS								
	-82.89	(0.00)	-17.83	(0.68)				
SFPTV	0.51	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
VID	-3.13	(0.44)	-5.07	(0.10)	-5.15	(0.09)	-5.16	(0.09)
WU	6.35	(0.08)	2.73	(0.32)	2.80	(0.30)		
CF	7.51	(0.00)	2.46	(0.41)	1.26	(0.00)	1.25	(0.00)
TV	-0.02	(0.00)	-0.006	(0.03)	-0.006	(0.02)	-0.006	(0.03)
AR(1)			0.76	(0.00)	0.77	(0.00)	0.77	(0.00)
R-squared	0.64		0.84		0.84		0.84	
Adjusted R-squared	0.64		0.84		0.84		0.84	
Durbin-Watson	0.55		2.26		2.38		2.38	
F-statistic	180.09	(0.00)	450.37	(0.00)	541.32	(0.00)	675.75	(0.00)

From a first look at the regression applied to the original model, we can see that most of the variables are significant. Furthermore, we can see that the adjusted R-squared of 0.64 is quite high. However, the Durbin–Watson statistic of 0.55 is low and indicates that the model suffers from autocorrelation. In order to correct the autocorrelation we include in the regression an autoregressive error term – AR(1). By using the Cochrane-Orcutt procedure, AR(1) calculates firstly, the correlation coefficient of the current residual and the lagged residual. We then re-estimate the equation by incorporating the residual from the past observation into the regression model for the current observation. Through this process we correct the autocorrelation. The strategy is, first, to try AR(1), and if the autocorrelation is not corrected, to try and correct it with an AR(2) term, and so on. The results obtained from estimating model 1 with an AR(1) term are shown in Table 7.4.

The inclusion of the AR(1) term does appear to correct the autocorrelation as the Durbin-Watson statistic of 2.26 falls in the inconclusive area. Furthermore, the

adjusted R-squared has increased and become 0.84 which suggests that changes in the independent variables can explain 84% of the variation in COP. Additionally, the F-statistic is significant which means that the regression as a whole is significant.

Our next step is to exclude the constant term since it is not significantly different from zero. Having excluded the constant, we can see that all variables are significant, apart from AIU. Even AID is significant in a one-tailed test, as the sign of the coefficient is the expected one. The reason for stating this is that for AID it is logical to expect a negative sign as it is asymmetric information that enters the market and causes the index to have negative returns. As the underlying price falls, option prices fall as well.

Finally, we exclude the insignificant variable, *AIU*, from the model. The final regression of model 1 now seems to be a valid regression as it has a high adjusted R-squared value of 0.84 and does not suffer from autocorrelation. Additionally, AID is still significant in a one-tailed test. Finally, the F-statistic is very high and significant. The regression shows that the calculation of the BSOPM, based on true volatility and future prices of the index has a significant effect on market option prices. However, asymmetric information, which causes the index to fall, is also significant. The significance of true volatility and asymmetric information suggests that market anomalies do play a significant part in option pricing. Finally, we must also comment on the significance of the TCF and OTV variables. As we can see, transaction costs and transaction volumes have a significant effect on option prices. Remember that the BSOPM assumes that there are no transaction costs in the market and does not take transaction volumes into consideration (see Appendix 11).

7.3.1.2. Analysis of model 2

The results obtained from estimating model 2, using the method of OLS with White heteroscedasticity-consistent standard errors, are summarised in Table 7.5.

Table 7.5: Model 2 – Results

Dependent Variable: COP	Original Model		AR(1) included		No insignificant variables	
	Coefficients	Prob.	Coefficients	Prob.	Coefficients	Prob.
Method: OLS						
C	-136.12	(0.00)	-141.61	(0.00)	-142.19	(0.00)
BSSPTV	0.83	(0.00)	0.82	(0.00)	0.82	(0.00)
AID	-1.52	(0.68)	0.39	(0.90)		
AIU	10.25	(0.00)	6.27	(0.04)	6.43	(0.03)
TCI	10.15	(0.00)	10.55	(0.00)	10.63	(0.00)
OTV	-0.01	(0.00)	-0.005	(0.06)	-0.005	(0.07)
ITV	0.0000004	(0.08)	0.0000001	(0.33)		
AR(1)			0.65	(0.00)	0.65	(0.00)
R-squared	0.71		0.82		0.83	
Adjusted R-squares	0.70		0.82		0.82	
Durbin-Watson	0.73		2.25		2.25	
F-statistic	202.36	(0.00)	340.65	(0.00)	476.86	(0.00)

Examining the t-statistics and the estimated coefficients in the original model, we can see that most of the variables are significant at the 5% level. Adjusted R-squared is quite high (0.71). However, once again, we can see that this regression suffers from autocorrelation (DW = 0.73). We include an AR(1) term for the same reason as above.

By including the AR(1) term, we can see that the autocorrelation problem has almost been solved, as the DW-statistic of 2.25 is very close to the upper boundary (but is in the inconclusive area). Additionally, adjusted R-squared has increased to 0.83. However, AID and ITV are not significant in this model. So in the next step we exclude these insignificant variables.

Having removed the variables that are not significant, we observe that the remaining variables are still significant. The adjusted R-squared is still 0.83, which suggests a good fit, and the F-statistic is still significant. We can observe again that true volatility has a significant effect on option prices. The asymmetric information variable (AIU) is again significant and transaction costs (TCI) and transaction volumes (OTV) are significant at the 10% level as well. So in this regression we have further evidence that market anomalies do affect market option prices.

In this part of the tests, we have tried to examine whether true volatility, in combination with the other independent variables, has a significant influence on COP. We are able to conclude that the BSOPM, based on true volatility and adjusted for transaction costs, transaction volumes and asymmetric information, is a good predictor of COP. This is very encouraging as it suggests that true volatility is important and needs to be predicted correctly, and that market anomalies such as asymmetric information, transaction volumes and transaction costs have a significant effect on the option prices (see Appendix 12).

In the next section, we include the BSOPM prices that have been calculated based on *implied* volatility.

7.3.2. Models based on implied volatility

7.3.2.1. Analysis of model 3

The results obtained from estimating model 3 using the method of OLS with White heteroscedasticity-consistent standard errors are shown in Table 7.6.

Table 7.6: Model 3 – Results

Dependent Variable: COP	Original Model		AR(1) Included		No constant term		No insignificant variables	
	Coefficients	Prob.	Coefficients	Prob.	Coefficients	Prob.	Coefficients	Prob.
Method: OLS								
C	5.45	(0.71)	-31.18	(0.16)				
BSFPIMV	0.78	(0.00)	0.69	(0.00)	0.71	(0.00)	0.71	(0.00)
AD	-1.55	(0.64)	-2.52	(0.41)	-2.68	(0.38)		
AU	3.10	(0.17)	1.97	(0.43)	2.15	(0.40)		
TCF	0.14	(0.89)	2.91	(0.06)	0.77	(0.00)	0.75	(0.00)
OTV	-0.01	(0.00)	-0.006	(0.02)	-0.007	(0.01)	-0.006	(0.01)
AR(1)			0.53	(0.00)	0.53	(0.00)	0.53	(0.00)
R-squared	0.83		0.87		0.88		0.88	
Adjusted R-squared	0.83		0.86		0.87		0.87	
Durbin-Watson	1.00		2.26		2.26		2.25	
F-statistic	498.02	(0.00)	587.76	(0.00)	703.27	(0.00)	1170.30	(0.00)

As we can see, the regression has a very high R-squared (0.83) and a highly significant F-statistic. However, most of the variables are not significant. The exceptions are BSFPIMV and OTV. However, as in the previous two cases, the regression suffers from autocorrelation, as the DW-statistic is 1.0. In order to correct the autocorrelation, we include an AR(1) term in the regression.

The inclusion of the AR(1) term has corrected the autocorrelation, as now the DW-statistic is 2.26. This regression now seems to provide evidence that transaction costs and volumes affect option prices. The adjusted R-squared value has increased to 0.88, which is a good indication that the regression is significant. However, asymmetric information does not seem to have a significant effect on COP. In the next step, we exclude the constant term and then we also exclude the remaining insignificant variables. The remaining coefficient estimates are still significant, the R-squared value is unchanged at 0.876 and the F-statistic is significant. Also, the model no longer suffers from autocorrelation.

The conclusion that we can draw from this regression is that market depth (as measured by transaction volumes) and transaction costs do influence option prices at a significant level. The BSOPM does not take transaction volumes into consideration

and assumes that there are no transaction costs (see Appendix 13). All of our regression results so far show that the exclusion of these two variables is a major disadvantage for the fair pricing of options.

7.3.2.2. Analysis of model 4

The final part of our regression analysis consists of the estimation of model 4.

The results obtained from estimating this equation, using the method of OLS with White heteroscedasticity-consistent standard errors, are summarised in Table 7.7.

Table 7.7: Model 4 – Results

Dependent Variable: COP	Original Model		AR(1) included		No insignificant variables	
	<i>Coefficients:</i>	<i>Prob.</i>	<i>Coefficients:</i>	<i>Prob.</i>	<i>Coefficients:</i>	<i>Prob.</i>
Method: OLS						
C	-133.90	(0.00)	-152.07	(0.00)	-156.49	(0.00)
BSSPIMV	0.95	(0.00)	0.86	(0.00)	0.86	(0.00)
AID	1.07	(0.70)	2.23	(0.45)		
AIU	5.27	(0.01)	3.60	(0.10)	3.41	(0.11)
TCI	9.16	(0.00)	10.67	(0.00)	10.93	(0.00)
OTV	-0.003	(0.25)	-0.003	(0.25)		
ITV	1.90E-08	(0.90)	5.97E-08	(0.66)		
AR(1)			0.42	(0.00)	0.41	(0.00)
R-squared	0.85		0.87		0.87	
Adjusted R-squares	0.85		0.87		0.87	
Durbin-Watson	1.23		2.17		2.18	
F-statistic	465.39	(0.00)	479.68	(0.00)	839.81	(0.00)

Here we can see that OTV, ITV and AID are not significant in the original model. Once again, the R-squared value and F-statistic are very high and significant, and once again, the regression suffers from autocorrelation. In order to correct the autocorrelation, we include again an AR(1) term. The results are shown in Table 7.7.

The inclusion of AR(1) in the regression corrects the autocorrelation, and the adjusted R-squared and the F-statistic both increase, to 0.87 and 479.7 respectively.

Next, we exclude the insignificant variables, but continue to include AIU, which is just significant at the 10% level in a one-tailed test. Again, we regard a one-tailed test as appropriate since the coefficient sign of AIU is the expected one.

After the exclusion of the insignificant variables, we can see that the remaining variables are still significant, as before. Additionally, adjusted R-squared is very high and the F-statistic is significant. The DW-statistic of 2.18 shows that the regression does not suffer from autocorrelation. AIU is still significant at the 10% level in a one-tailed test.

In general, this regression provides support for the argument that transaction costs and AIU have significant effects on option prices, evidence which was also found in the previous regressions (see Appendix 14).

7.3.3. The final regression equations

The analysis of the four models enables us to generate important conclusions. In particular, we are able to report evidence that true volatility influences option prices in a significant way. Furthermore, we are able to identify the anomalies that have a significant effect on option prices, such as asymmetric information, transaction costs and transaction volumes.

The final results for the four models, with corrected autocorrelation and all insignificant variables excluded, are summarised below.

Model 1

$$COP = 0.71BSFPTV + 1.25TCF - 0.006OTV - 5.16AID + 0.77AR(1) + e_1$$

(14.87) (6.80) (-2.09) (-1.65) (21.7)

Model 2

$$COP = -142.19 + 0.82BSSPTV + 10.63TCI - 0.005OTV + 6.43AIU + 0.65AR(1) + e_2$$

(-4.15) (12.39) (4.52) (-1.83) (2.13) (12.14)

Model 3

$$COP = 0.71BSFPTIMV - 0.006OTV + 0.75TCF + 0.53AR(1) + e_3$$

(20.39) (-2.40) (5.56) (10.26)

Model 4

$$COP = -156.49 + 0.86BSSPIMV + 10.93TCI + 3.41AIU + 0.41AR(1) + e_4$$

(-8.61) (17.15) (8.47) (1.55) (6.43)

(Residual plots and fitted values are shown in Appendices 11, 12, 13, 14)

In the next section, we conduct some further tests on the variables and residuals of these regressions.

7.3.4. Further tests on the final regression equations

7.3.4.1. Testing the BSOPM variations

As we stated in the hypotheses at the beginning of this chapter, the coefficients on the BSOPM variations should not be significantly different from one. To test this, we use:

$$t - statistic = \left(\frac{\text{coefficient} - 1}{\text{standard error}} \right)$$

The results are shown below:

	t-statistic
BSFPTV	-5.83*
BSSPTV	-2.72*
BSFPIMV	-8.28*
BSSPIMV	-2.68*

Significant at 5% level

The coefficients of the BSOPM variations are all significantly different from one. This is another indication of inefficiency and another indication that the BSOPM is not appropriate for emerging markets.

7.3.4.2. Tests for redundant variables

In this section, we test whether the inclusion of the extra variables in addition to the BSOPM theoretical prices, i.e. TCF, OTV, ITV, AIU and AID, has a significant effect on the regression. The hypotheses to be tested for each model are:

H_0 : the extra variables have no significant effects

H_1 : the extra variables have significant effects

The results are summarised in Table 7.8.

Table 7.8: F and LR Tests of Redundant Variables

Test on Redundant Variables	<i>F-statistic</i>	<i>Prob.</i>	<i>Log-Likelihood Ratio</i>	<i>Prob.</i>
Model 1 (Redundant Variables: AID, TCF, OTV)	14.26	(0.00)	41.46	(0.00)
Model 2 (Redundant Variables: AIU, TCI, OTV)	10.17	(0.00)	29.98	(0.00)
Model 3 (Redundant Variables: OTV, TCF)	20.96	(0.00)	40.57	(0.00)
Model 4 (Redundant Variables: AIU, TCI)	37.70	(0.00)	70.88	(0.00)

The F-statistic and the likelihood ratio are both significant in all the four equations. Hence we can reject the null hypothesis and conclude that the extra variables do affect option prices significantly.

7.3.4.3. Chow forecast test on the models

Another test of the validity of the four models is a Chow forecast test. In order to perform this, we take a sub-sample of 250 observations (observations for year 1) and predict the remaining 250 sample values (observations for year 2). For each model, the hypotheses to be tested are:

H_0 : The sub-sample can predict the values for the remaining sample

H_1 : The sub-sample cannot predict the values for the remaining sample

The results are shown in Table 7.9.

Table 7.9: Chow Forecast test results

Chow Forecast: Forecast from 250 to 500	<i>F-statistic</i>	<i>Prob.</i>	<i>Log-Likelihood Ratio</i>	<i>Prob.</i>
Model 1	0.46	(1.00)	193.49	(0.99)
Model 2	0.41	(1.00)	178.20	(0.99)
Model 3	0.46	(1.00)	193.83	(0.99)
Model 4	0.67	(0.99)	263.18	(0.28)

The reason for taking a sub-sample of 250 observations is that we wanted to test whether the first year's results can predict the second year's prices. In all four models, the F-statistic and the Log-Likelihood are not significant, meaning that we cannot reject the null hypothesis that the sub-sample can predict the remaining sample values. This is an important result as it shows the ability of the regressions to make predictions and so enhances their validity.

7.3.4.4. Chow Breakpoint test on the models

The Chow Breakpoint test on the four models is performed in order to check for any structural break between 2000/01 and 2001/02 i.e. whether the independent variables have significant effect on option prices on both years. The results are shown in table 7.10.

H_0 : there is not a structural change between 2000/01 and 2001/02

H_1 : there is a structural change between 2000/01 and 2001/02

Table 7.10.: Chow Breakpoint test results

Chow Breakpoint test: at 250 observation	F-statistic	Prob.	Log-Likelihood Ratio	Prob.
Model 1	0.69	(0.62)	3.54	(0.62)
Model 2	1.22	(0.29)	7.48	(0.28)
Model 3	1.45	(0.21)	5.88	(0.21)
Model 4	4.90	(0.00)	24.41	(0.00)

The table above shows that only *model 4* shows signs of structural break i.e. that 2000/01 results differ from 2001/02 year's prices. However as we can see in Appendix 15, where we have the regressions results for each year individually, we can observe that there is no structural changes between the two years of study, as the results are very similar.

7.3.4.5. Comparing fitted values with BSOPM values

Having determined the preferred regression equations for each of the four models, we now make some comparisons between the fitted values, the BSOPM prices and the market prices, by calculating the root mean squared error (RMSE) of the residuals. The hypotheses to be tested are the following:

H_0 : the fitted values do not generate lower RMSE than the BSOPM values

H_1 : the fitted values generate lower RMSE than the BSOPM values

The root mean squared error formula is:

$$RMSE = \sqrt{\frac{\sum resid^2}{N}}, \text{ where the numerator is the sum of squared residuals and } N$$

represents the number of observations.

In order to perform the test, we use the regression residuals and the residuals of the BSOPM theoretical values (i.e. market values (COP) – BSOPM values (BSFPTV, BSSPTV, BSFPIMV, BSSPIMV)). The results are shown in the table below:

Table 7.11.: Root Mean Square Error results

	Root Mean Square Error
Model 1	9.78
BSFPTV	17.75
Model 2	10.31
BSSPTV	18.41
Model 3	8.75
BSFPIMV	13.05
Model 4	8.92
BSSPIMV	11.65

At this table we show the RMSE results for each regression model compared with the appropriate BSOPM variation. As we can see, comparing the appropriate regression equations with the appropriate BSOPM prices, the RMSE in all four models is lower than the RMSE of the BSOPM prices

Hence, we can reject the null hypothesis for the equality between the RMSE of the regression fitted values and the BSOPM prices. As we can see, the RMSE of the regression equations are much lower than those of the BSOPM prices. This is a very important result as it shows that the BSOPM is not performing well in the Greek market and that the inclusion of the market anomalies and the correct estimation of volatility produce prices that are closer to the market prices.

7.3.5. Summary of the results

The results obtained from estimating the four regression models may be summarised as follows:

- The BSOPM variables (BSFPTV, BSSPTV, BSFTIMV, BSSPIMV) are all significant, as expected. Their signs are also the expected ones, as the BSOPM is directly related to the COP. Additionally, we can observe that the BSFPTV and BSFPIMV are more significant than BSSPTV and BSSPIMV respectively. This was expected as the ADEX market provides the daily option prices for the call options on the FTSE/ASE 20 based on the futures prices of the index, rather the spot index level.
- True volatility is indeed an important influence on COP as the BSOPM variations that use true volatility instead of implied volatility (BSFPTV and BSSPTV)

produce significant results. In Chapter 6, the results of the tests of true versus implied volatility also directed us to the conclusion that implied volatility is a mis-estimation of true volatility and thus distorts market option prices i.e. it creates option mis-pricing.

- Other important factors that influence option prices are the option's transaction volumes, total transaction costs on buying/selling the option and future contracts and asymmetric information/insider trading, all of which cause the index to be priced inefficiently. Based on these regressions we were able to show that these market anomalies do have a significant effect on option prices and that the normality and perfect market assumptions of the BSOPM are too strict and create pricing problems.
- The daily option's transaction volume (OTV) is a significant influence in models 1, 2 and 3. Transaction costs (TCF and TCI) are significant in all four models. Both the transaction volumes and costs could be used as market depth measures. The higher the transaction volumes, the stronger the market and the lower the transaction costs, the greater the number of investors, so the higher the competition and the more efficient the asset pricing is. This argument also appears in a different format in the efficient market hypothesis.
- AID and AIU (the asymmetric information and insider trading variables) are also significant. If markets are perfect, then there are no signs of asymmetric information or insider trading. However, in imperfect market we can observe such signs. In Chapter 6, we were able to conclude that the ASE is not an efficient market and that there are signs of asymmetric information and insider trading. The regression results also support and enhance the validity of these conclusions.

- The RMSE tests and the redundant variables tests support the view that market anomalies affect COP. The inclusion of these market anomalies in the regression equations produces a much lower RMSE than the BSOPM's four variations.

A very important conclusion is that the four models used the four variations of the BSOPM, i.e. they used future index levels as well as spot, and true volatility as well as implied. As we are able to observe, in all the four regressions, some of the market anomalies have a significant effect on option prices. Since *all four* variations of the BSOPM produce pricing errors, we can argue with some confidence that there are some serious problems with the BSOPM in the Greek market.

7.4. Conclusion

In this chapter, a number of tests have been performed. The purpose of all these tests was to demonstrate that market anomalies and the mis-estimation of volatility (since implied volatility is not a good approximation of the true volatility) cause option pricing problems in the ADEX. All the test results lend support to this argument.

CHAPTER 8: Conclusion

8.1. Summary and contribution of the thesis

This thesis is concerned with index options in emerging markets, with particular reference to Greece. Specifically, we have tried to identify whether the BSOPM is an appropriate model for emerging markets or whether it creates pricing problems. Additionally, we have tried to determine whether the stock and derivatives markets of Greece have anomalies that also create index option pricing problems. The option contract that was analysed was the at-the-money index option on the FTSE/ASE 20 index with expiration time of two months. The data used were daily observations from 9/2000 – 9/2002. The total sample size was 500 daily observations.

The study began with an exploration and review of the literature on the research area. The topics covered in the literature review included market anomalies and their effect on option prices, the efficiency of option and stock markets and the analysis and criticisms of the CAPM, EMH and BSOPM. The empirical studies that were analysed offered significant conclusions and we used them in order to produce hypotheses to be tested in the later chapters. Anomalies, such as high transaction costs and low transaction volumes, asymmetric information, insider trading, seasonality, predictability of indices and low efficiency or inefficiency in stock and option markets, were proposed as causes of option pricing problems. Additionally, there were many criticisms of the BSOPM. These criticisms were directed mainly at the assumptions of the model which could be characterised as strict. The major disadvantage of the model concerns implied volatility. Implied volatility is not a good approximation of historic volatility, and so creates mis-pricing in option premiums.

However, other assumptions, such as the underlying asset's normality, zero transaction costs and constant interest rates, have also been criticised.

The hypotheses derived from the conclusions of the empirical studies were then tested in later chapters, particularly in Chapter 6. The tests performed in this chapter yielded significant results. Indeed, the Greek market was shown to be inefficient and with many anomalies, such as high transaction costs, low transaction volumes, insider trading and asymmetric information. Apart from the tests on the ASE, we conducted tests on the ADEX and the BSOPM. The ADEX proved to be an efficient market in the sense that there were no arbitrage opportunities. Tests on the BSOPM showed that it is an inappropriate model for the ASE and ADEX. Implied volatility was not a good approximation of true volatility and according to Figure 6.3 it tends to create overvalued option contracts.

The significance of the anomalies was tested in Chapter 7. As we have said from the very beginning of the thesis, we are not interested simply in identifying anomalies in the ASE and in showing that the BSOPM is an inappropriate model for emerging markets. We are also interested in showing the significant effect that these anomalies have on option prices. In this regard, our findings are summarised in the next section.

8.2. Main conclusions

Volatility

- Implied volatility is not a good predictor of the true volatility. This mis-estimation of implied volatility produces mostly overvalued options, as shown in Figure 6.3.

Asymmetric information and insider trading

- Asymmetric information and insider trading have significant effects on option prices and the incorporation of this variable produces prices that are very close to market prices. As we observed, there is evidence that the AIU causes higher option prices (overvaluation) and that the AID causes lower option prices (undervaluation)

Transaction costs

- Transaction costs affect option prices significantly and this should not be ignored. The higher the transaction costs the higher the option prices. The higher the transaction costs the lower the number of investors in a market, as the market is more expensive. However, if a market has a lower number of participants, then it becomes more risky and thus option prices will be higher.

Transaction volumes

- Transaction volume, which is an indicator of market depth, also has a significant effect on option prices. The lower the transaction volume the more uncertainty there is in the market and thus the higher premiums that the investors have to pay.

Black and Scholes Option Pricing Model

- The incorporation of these anomalies and the replacement of implied volatility by true volatility create better results than the BSOPM. The Chow forecast test demonstrates the significance of the results, as it

shows that the regression equation has the ability to make accurate predictions. Also the regression equation predicts option prices closer to market prices, compared with the BSOPM.

The key contribution of the thesis is the identification of the anomalies in the ASE and how these anomalies affect option prices in the ADEX. Additionally, an important contribution is the analysis of implied volatility versus true volatility. Many studies have shown that there is a difference between implied and true volatility. Yet we have been able to demonstrate that replacing implied volatility with true volatility has a significant effect on option prices. Furthermore, the study is conducted in a market that is very new for Greece. Index options were only introduced by the ADEX in 9/2000 and so have had only 3 years of life. The study tries to show how the underlying market affects the option market, and explains that the BSOPM is only appropriate for strong-form efficient markets. For inefficient markets, the model is inappropriate. Usually in the financial world, the most inefficient markets are emerging markets. So it is clear that emerging markets require a revised BSOPM in order to avoid mis-pricing in option contracts.

8.3. Policy recommendations

This thesis produces two types of recommendation: policy recommendations and recommendations for future research. Policy recommendations refer to the ADEX and ASE which can utilise the empirical results in order to create a more competitive and more secure market. The following recommendations are proposed.

Asymmetric information and Insider trading

- New laws need to be enforced regarding insider trading and asymmetric information. The elimination of such events will increase the efficiency of the ASE. More specific mechanisms could be created which would protect non-insiders. E.g. insiders should inform the stock market for every transaction they want to make in the future and the intention from these insiders to sell or buy specific stocks and in specific quantities should be published in the daily financial newspapers.

Volatility and noise trading

- Investment seminars from ADEX and ASE should be offered with the aim of educating investors which will assist in the reduction of herding behaviour in the ASE. We argue that Greek investors need to become more educated in financial and stock market issues as Greek investors have been actively involved with the ASE only since the mid 90s. In addition only a very small percentage of the Greek population makes transactions in the ASE. As we know, herding behaviour creates several problems in a market. Specifically the reduction of noise trading and the better education of the investors will also improve the estimation of implied volatility.

Transaction costs and volumes

- ADEX and ASE could decrease their transaction costs and so to create a competitive market, which will, in turn, attract more investors. As we

were able to conclude from the main part of this research, the higher the number of investors the more efficient the market becomes.

Having summarised the policy recommendations we will present some recommendations for future research.

8.4. Recommendation for future research

The selected research topic is very wide. There are many sub-areas in which future research could be directed. We conclude by outlining some of the areas for future research.

Asymmetric information and Insider trading

- The present study used dummy variables in order to quantify the data. However, future research could develop and employ better models for transforming qualitative data, such as insider trading and asymmetric information, into quantitative data. There are models that measure asymmetric information, but they measure it on a yearly basis. Models should be developed that measure asymmetric information and insider trading on a daily basis as well.

Market depth

- Another area that needs further exploration is the area of market depth. Market depth can be measured from transaction volumes or from a combination of transaction costs and transaction volumes. Instead of

having these two variables, one variable could be constructed to measure market depth. In addition, market depth should be also made available for measurement on a daily basis rather than on yearly or monthly bases.

Index options

- The instrument under examination in this thesis was the at-the-money index option in the FTSE/ASE 20 index with two months to expiration. A justification for choosing this instrument was presented in the methodology chapter. However, further study could be made of other option contracts, such as stock options or options with higher expiration time. In addition, studies could focus not only on at-the-money options but also on out-of-the-money and in-the-money contracts.

Statistical and econometric tests

- Another recommendation concerns the methods that have been used in this study. We have used several traditional econometric and statistical methods, which have been well tried and tested for their effectiveness and reliability. However, additional research on the topic could take place, using other statistical and econometric models and methods, such as other GARCH models, fractional cointegrated models and non-linear chaotic models.

Black and Scholes Option Pricing Model

- A final area, in which further research could be directed, is the revision of the BSOPM. This would be a very difficult task. However, a revised BSOPM for emerging markets, which would incorporate all the identified anomalies, would be a breakthrough.

8.5. Conclusion

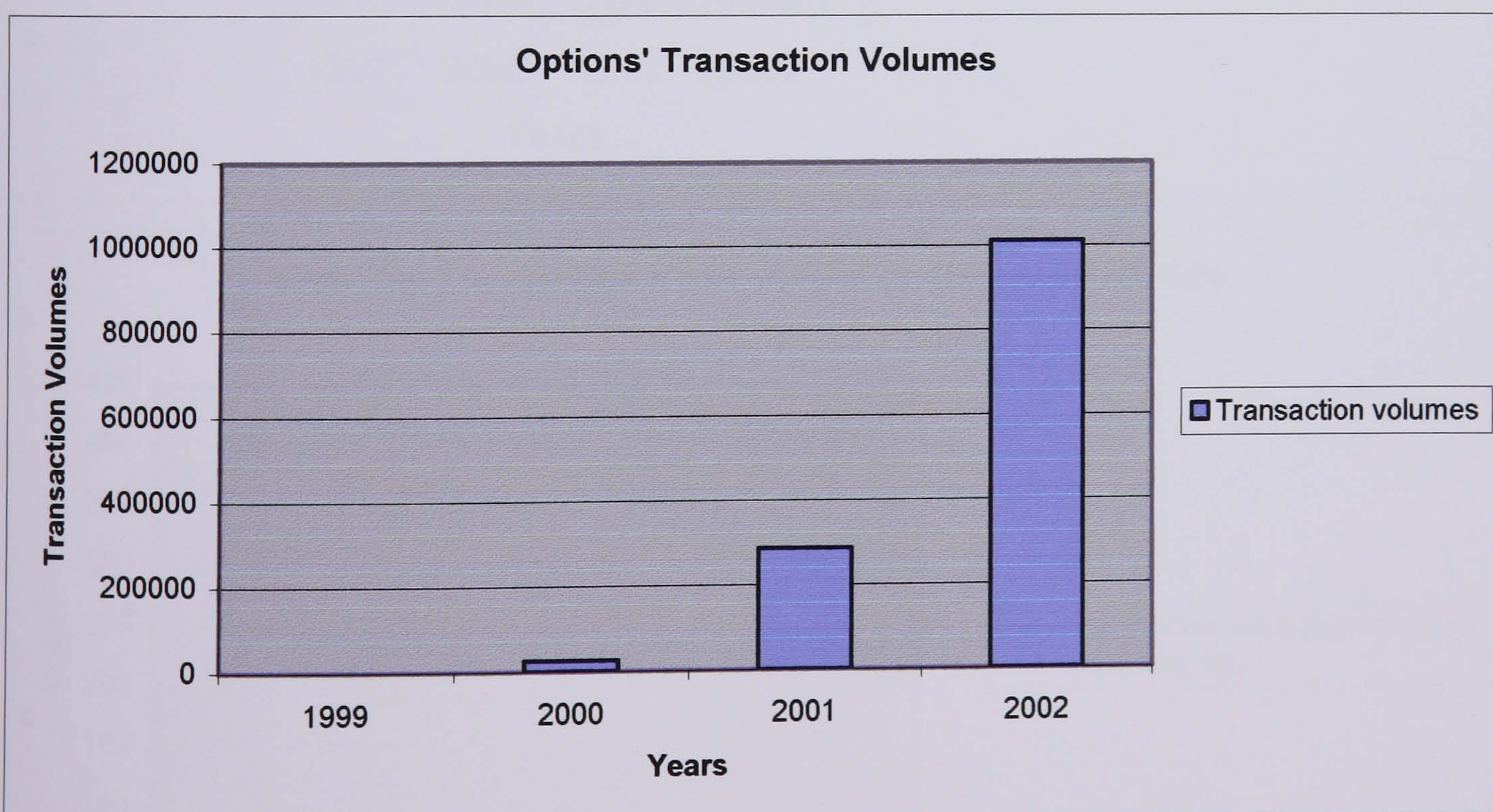
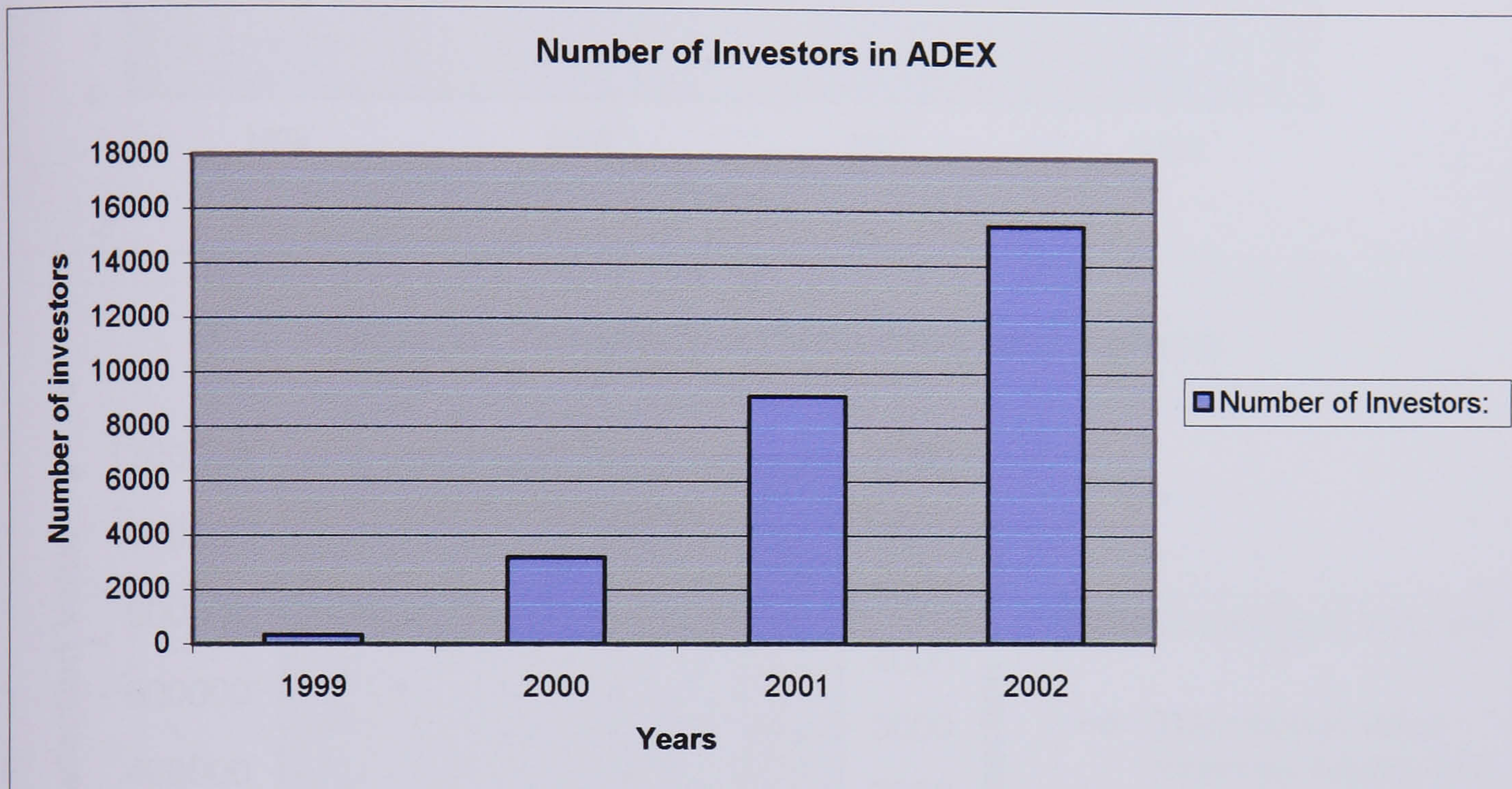
To conclude this study, I would like once again to point out the significance of the thesis. From the empirical results, several policy recommendations have been proposed, which can be utilised by ADEX and ASE in order to increase the efficiency of their operations. The policy recommendations can be used as guidance towards the improvement of the investment environment in Greece. In addition, similar studies could be conducted in other emerging markets, thereby strengthening and generalising our findings, which currently tend to have a domestic character. Furthermore, there are several research topics that could be explored in an attempt to provide greater insights to the academic community and practitioners.

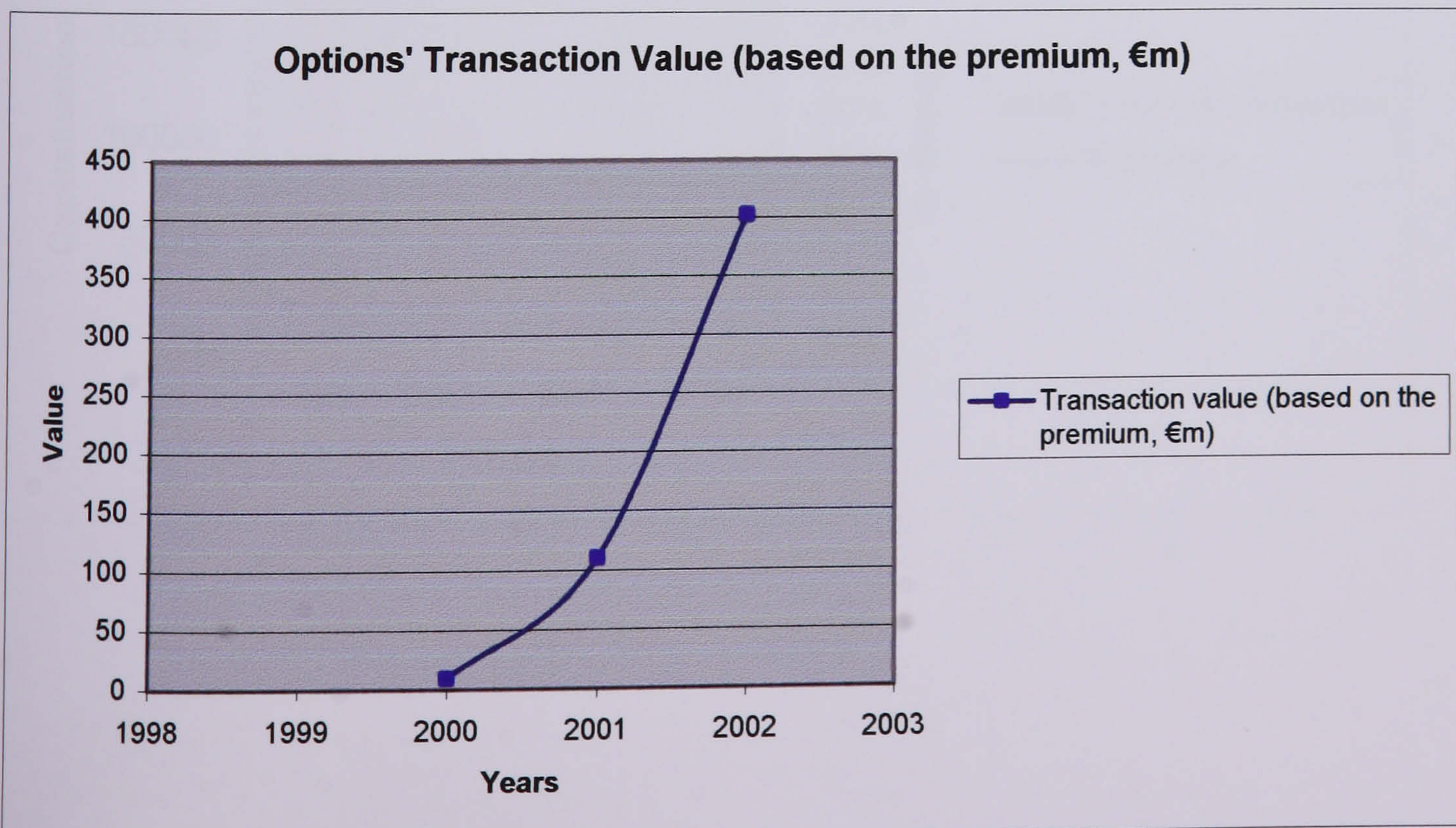
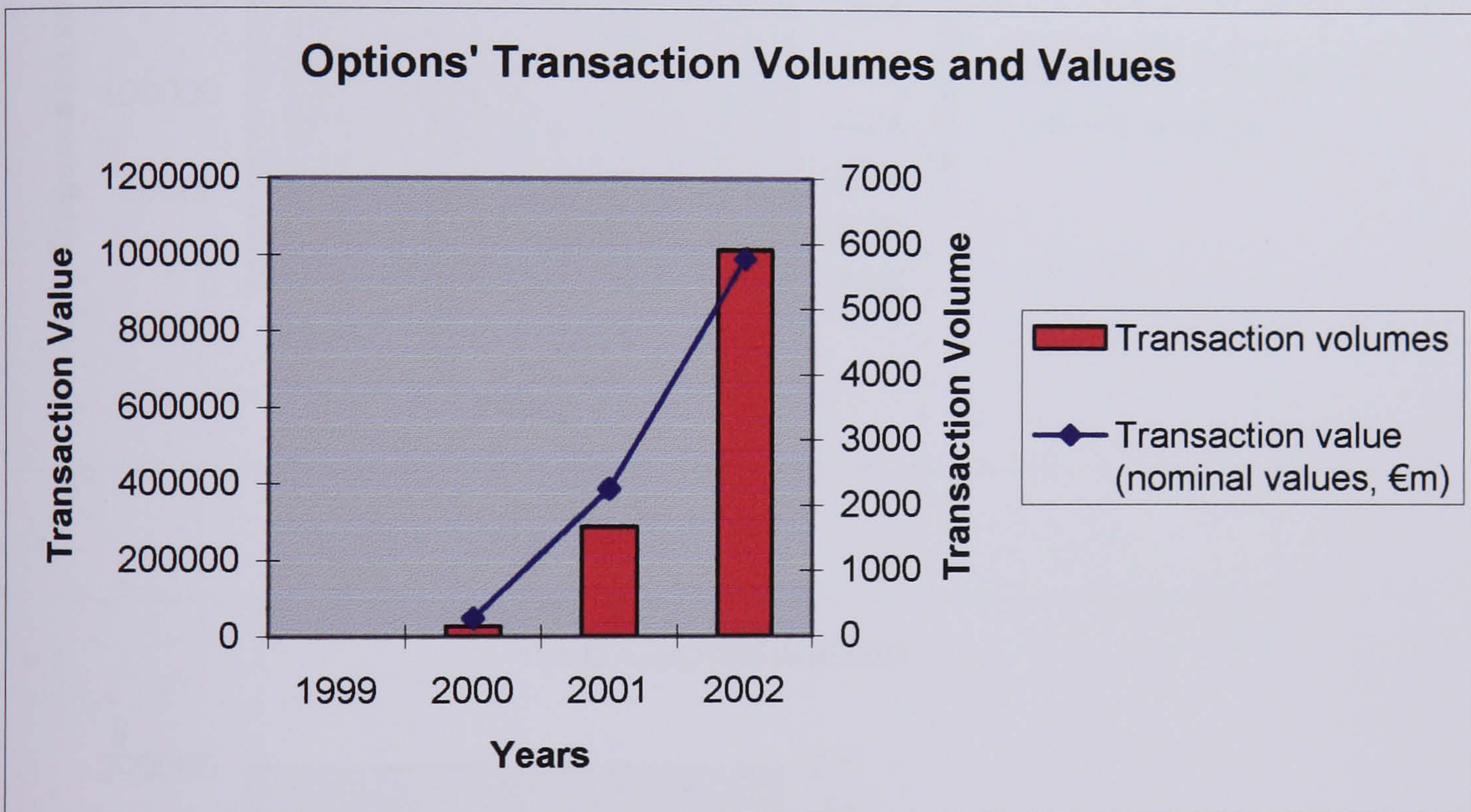
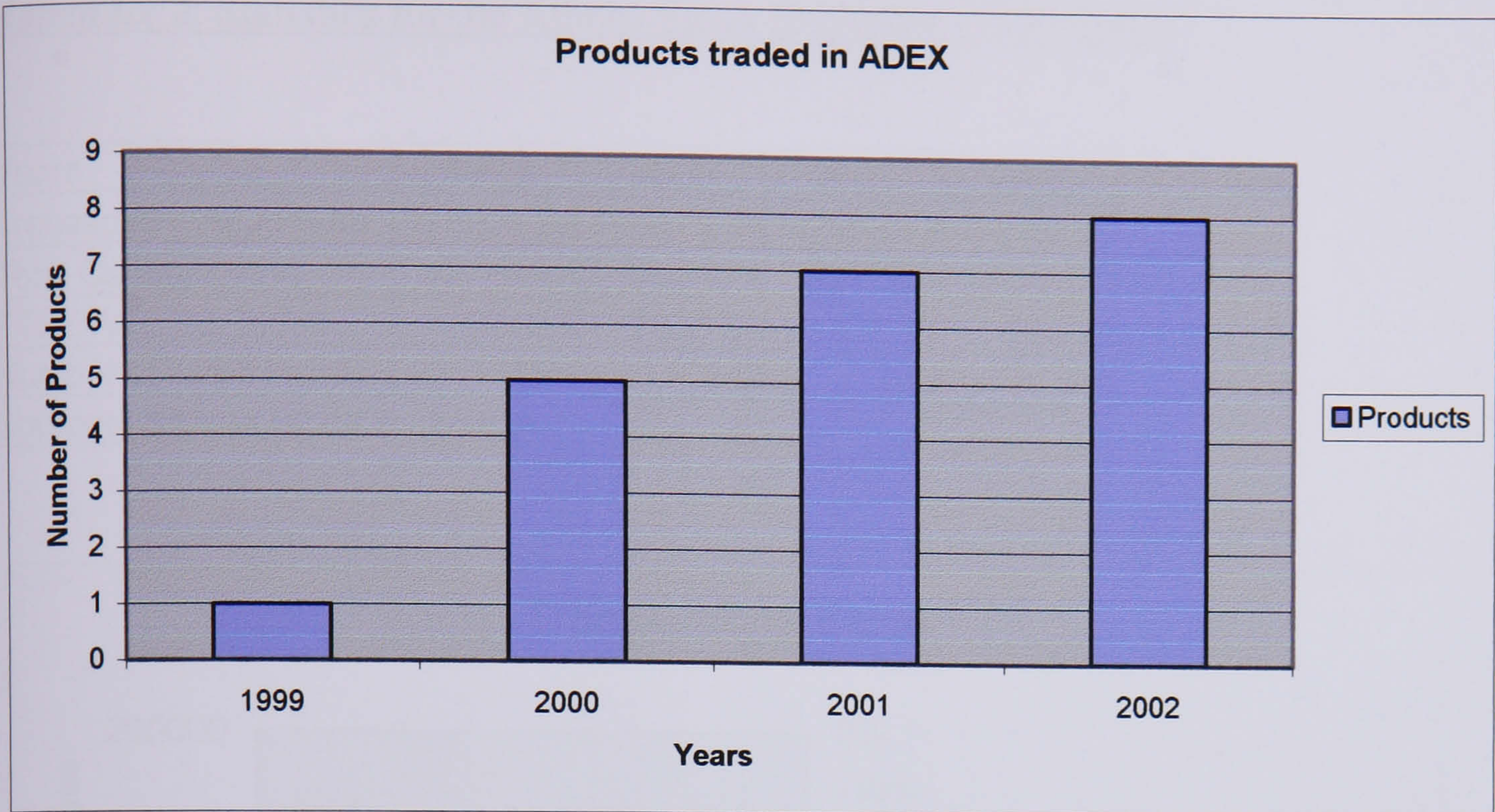
Appendices

Appendix 1: Statistics for the Athens Derivatives Exchange (1999-2002)

Years	1999	2000	2001	2002
Number of Investors:	325	3181	9133	15482
Products	1	5	7	8
Transaction volumes		26052	287055	1013194
Transaction value (nominal values, €m)		276,12	2255	5774,86
Transaction value (based on the premium, €m)		9.6	110.51	402.61

Source: Athens Derivatives Exchange

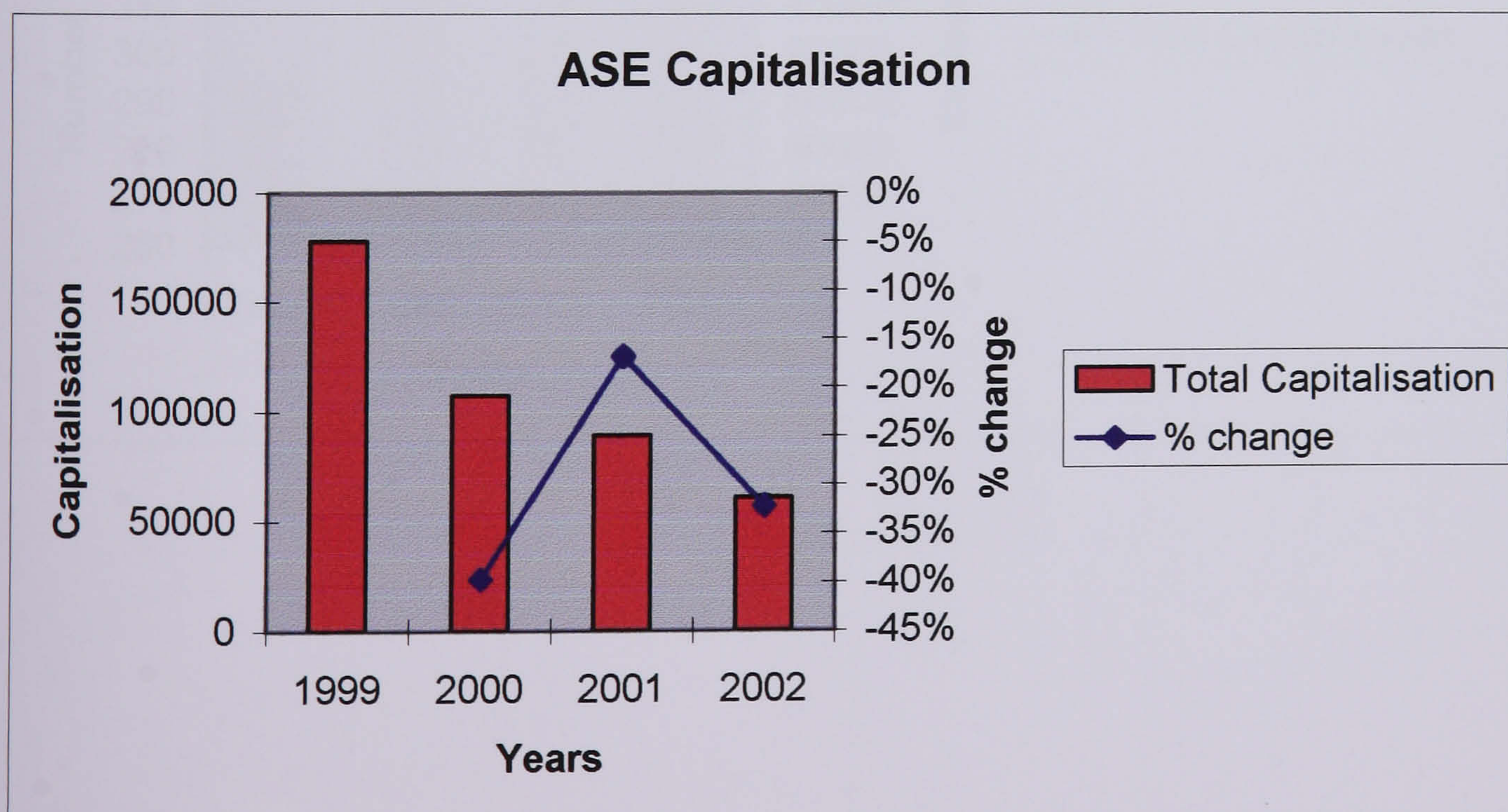
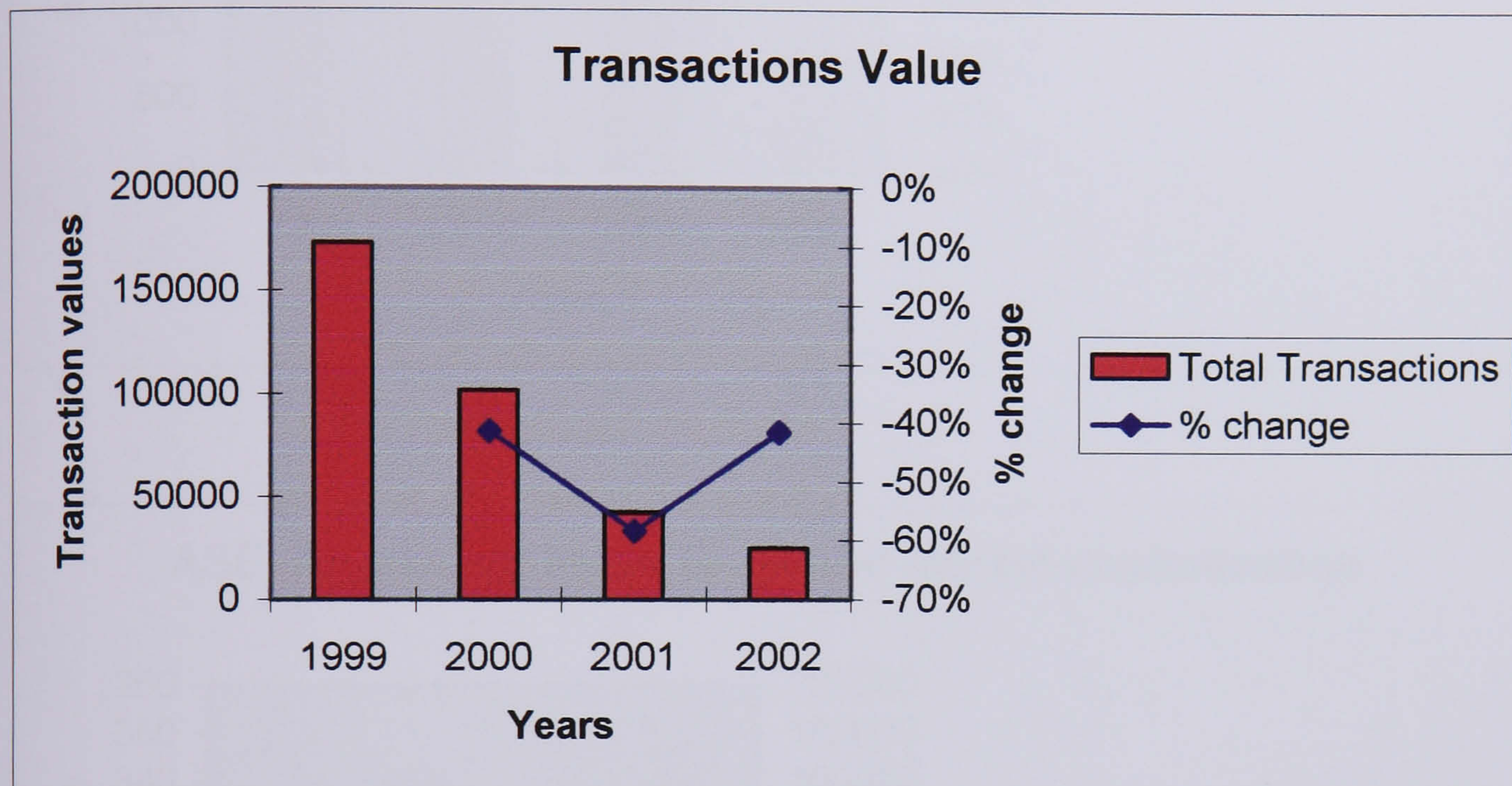




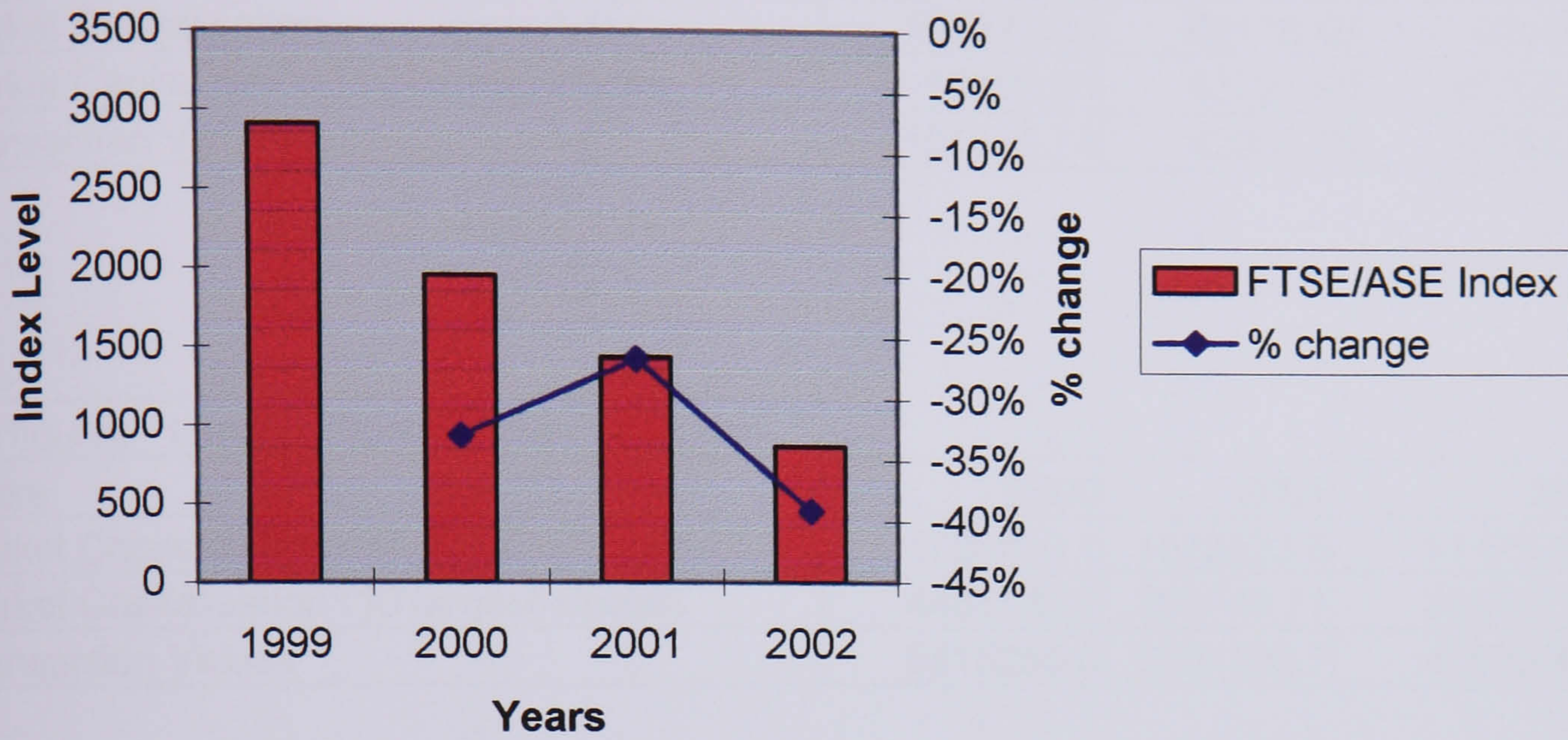
Appendix 2: Statistics for the Athens Stock Exchange (1999-2002)

Years	1999	2000	2001	2002
Transaction Value (€m)	173026.98	101675.74	42363.75	24784.05
Total Capitalisation	177890.4	107283.9	89178.5	60449.3
FTSE/ASE 20 Index	2910.1	1950.95	1428.91	869.48
Number of listed firms	294	342	349	348

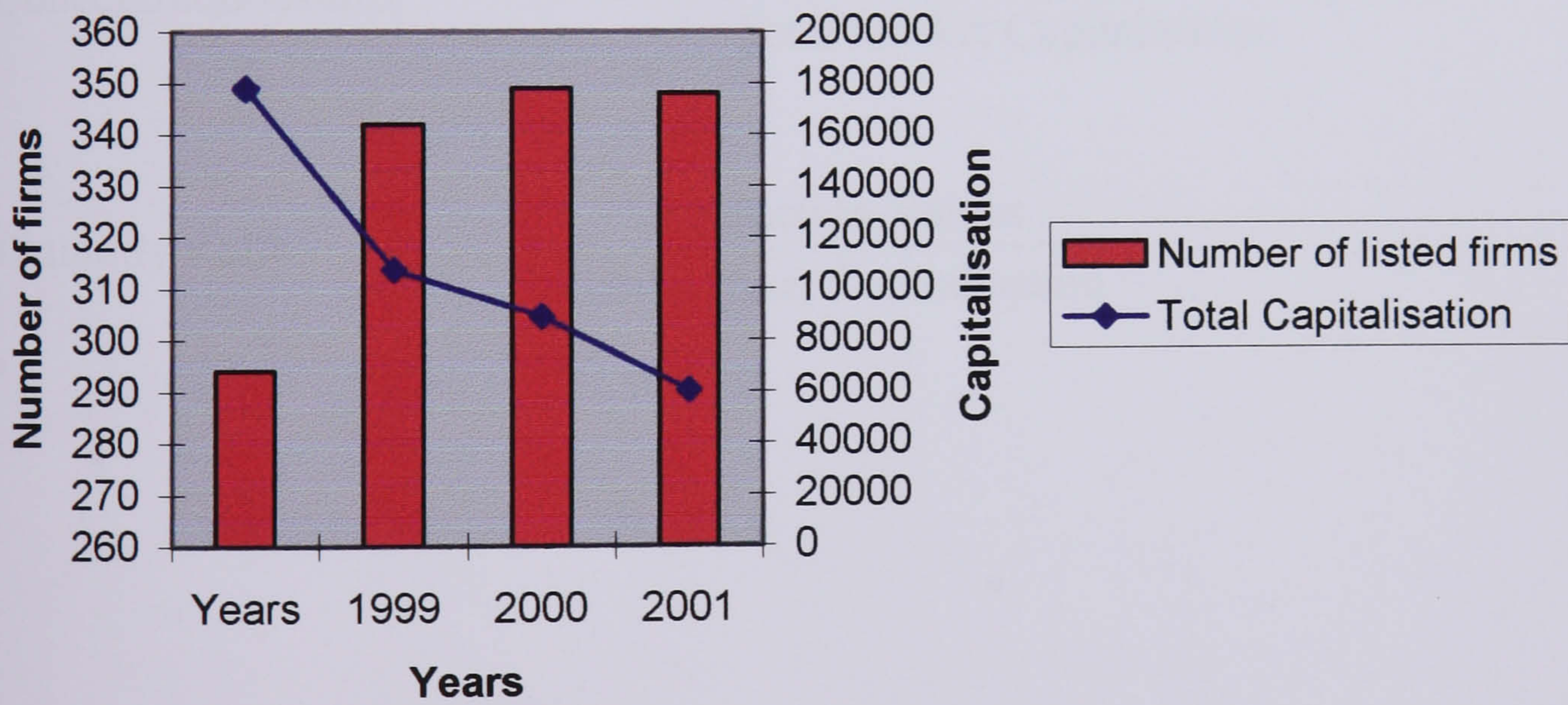
Sources: Athens Stock Exchange



FTSE/ASE 20 Index



ASE: Number of listed firms and market capitalisation



Appendix 3: Statistic figures for Greek and UK stock markets:

Greek figures - Athens Stock Exchange (in €m)			
Years	2000	2001	2002
Market Capitalisation	107283.93	89178.46	60449.3
Market Capitalisation (10 largest stocks)	50489.55	42797.95	36755.38
Transaction Values	101675.74	42363.75	24784.05

UK figures - London Stock Exchange (in £m)			
Years	2000	2001	2002
Market Capitalisation	1796810.7	1523523.5	1147827.3
Market Capitalisation (10 largest stocks)	448513.32	396748.71	368587.61
Transaction Values	5415255.6	5581186.7	4595350.9

Ratios:

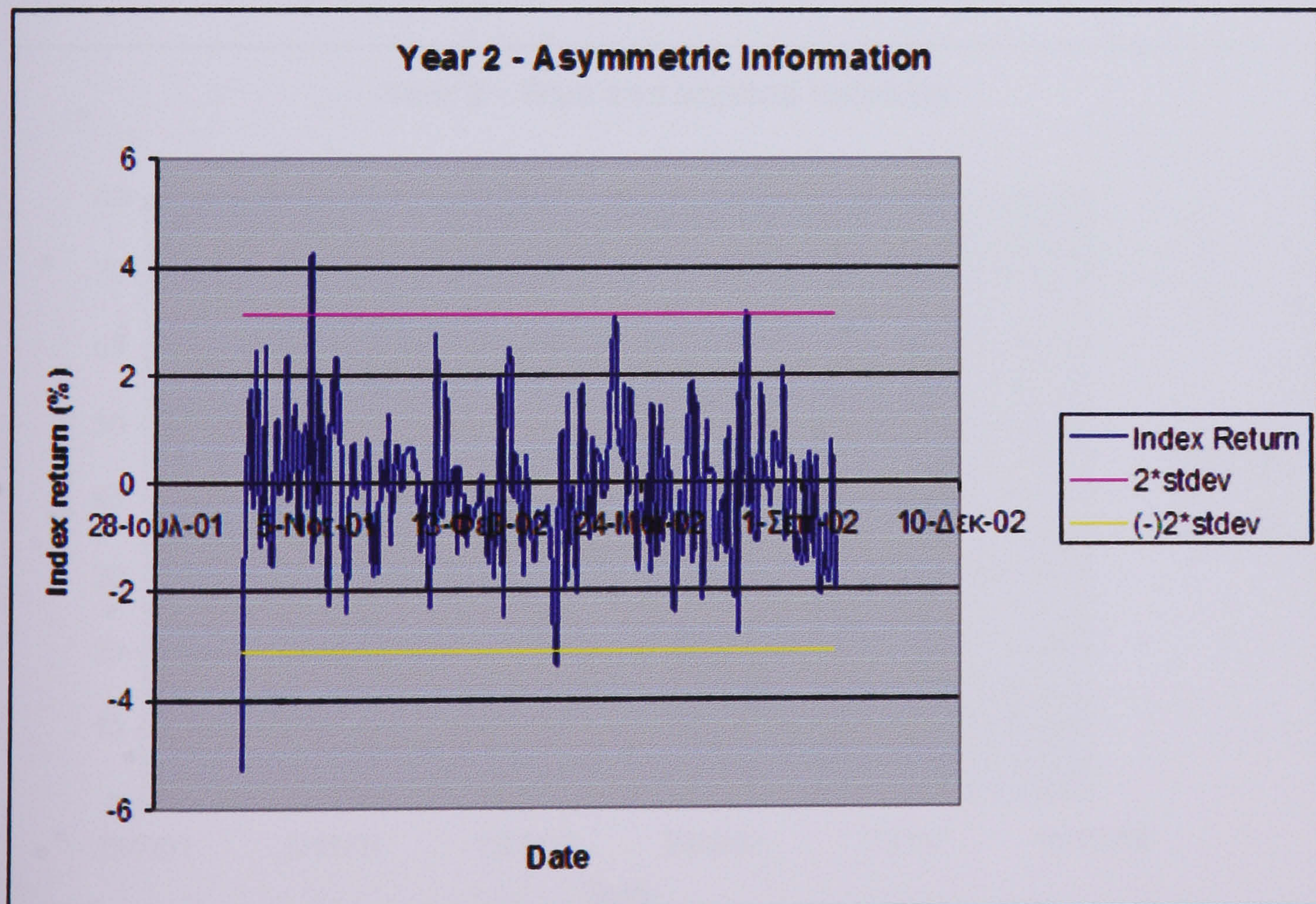
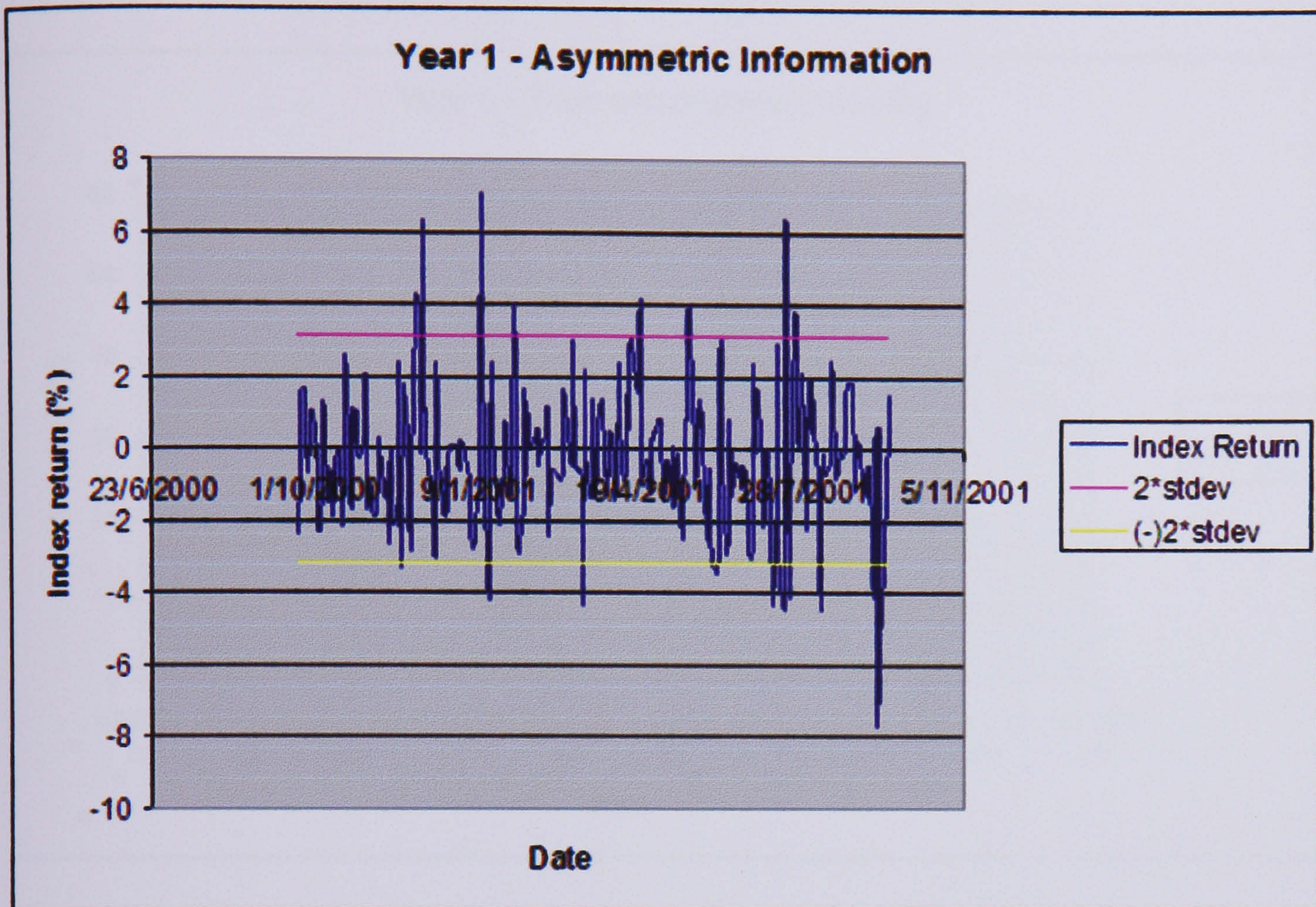
1. Concentration Ratio:
$$\frac{\text{Market Capitalisation of the 10 largest stocks}}{\text{Total Market Capitalisation}}$$

2. Liquidity Ratio:
$$\frac{\text{Transaction Values}}{\text{Total Market Capitalisation}}$$

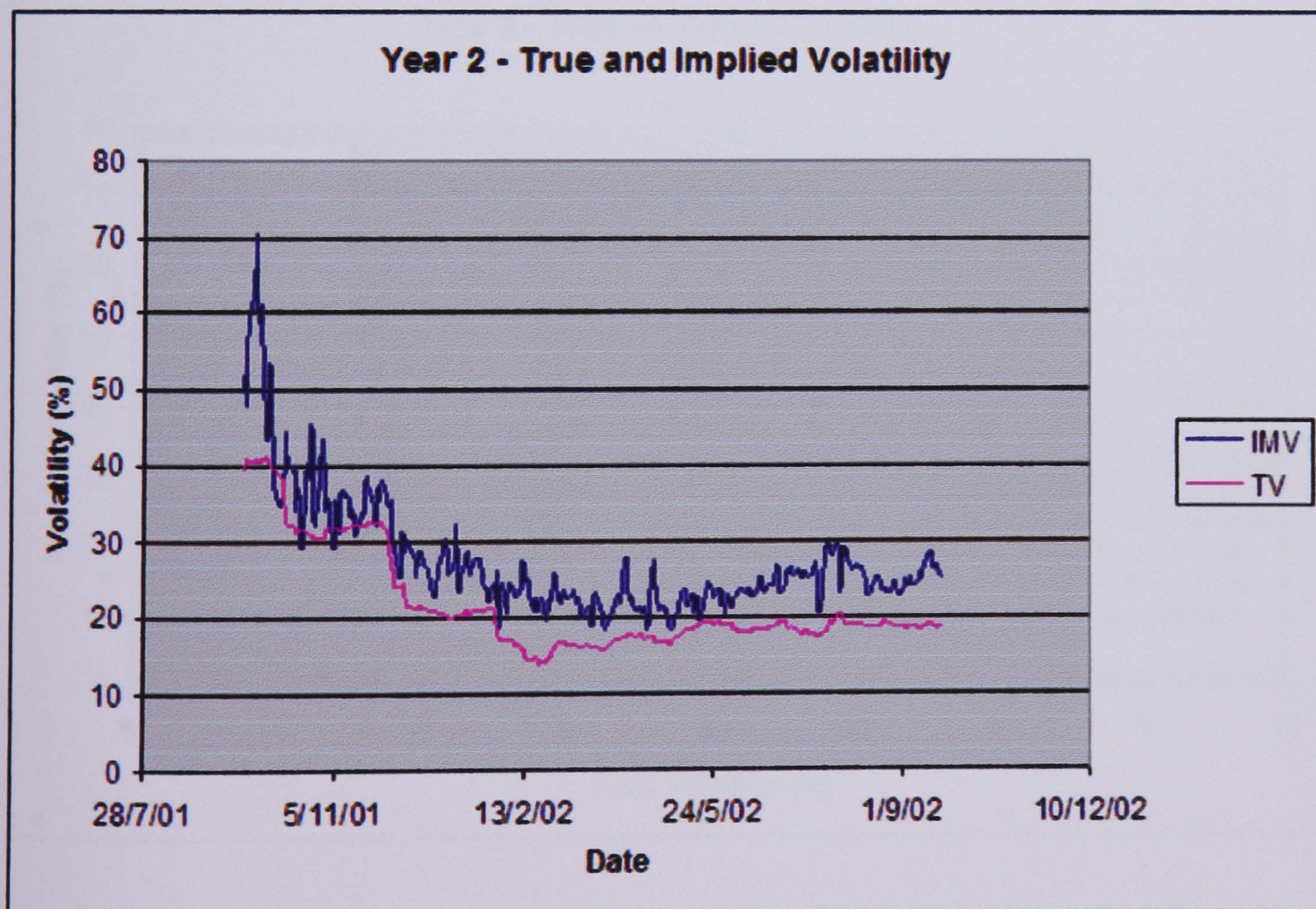
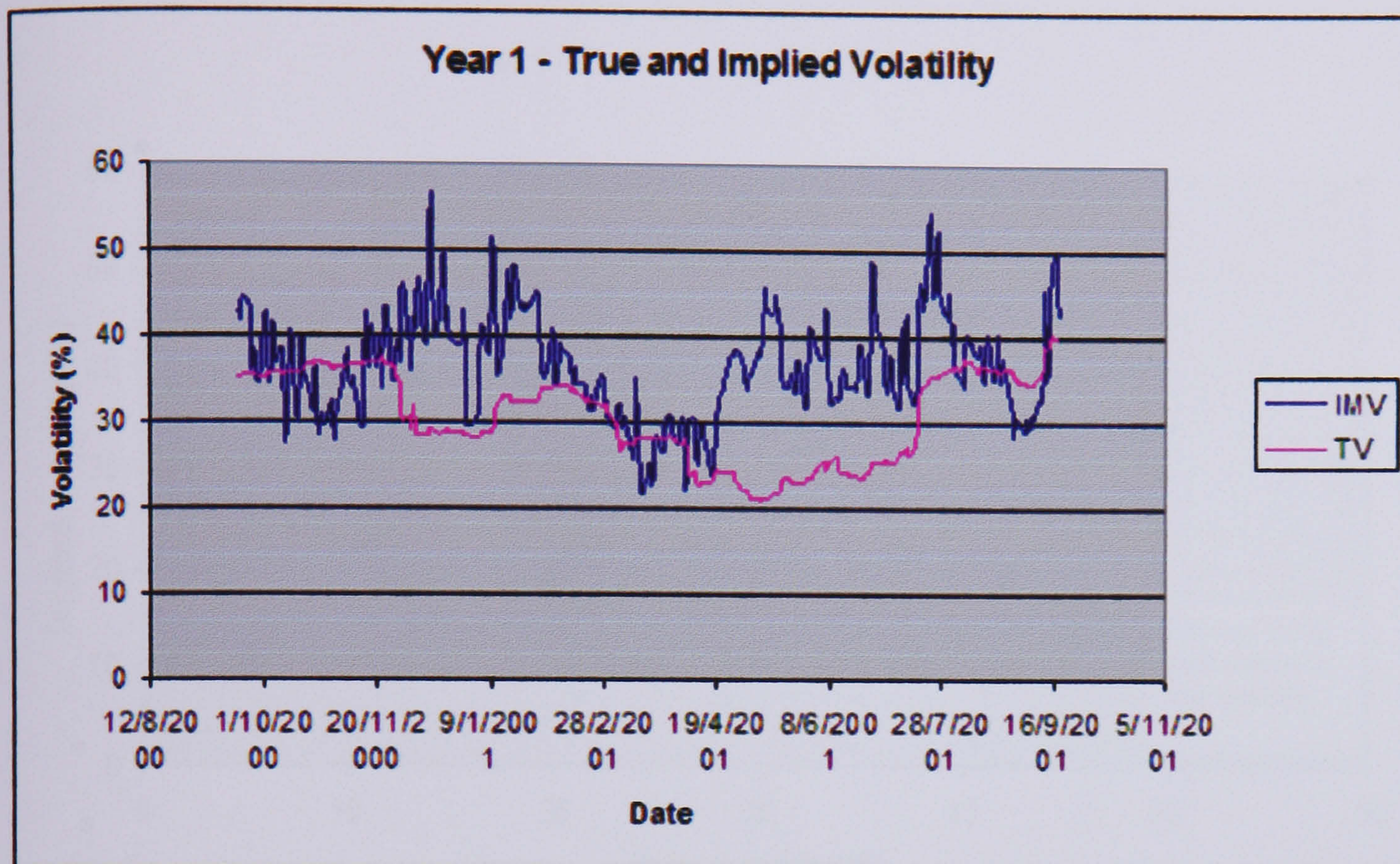
Appendix 4: FTSE/ASE 20 Index Composition:

Greek Aluminium	Cosmote
Alpha Bank	Motor Oil
Agricultural Bank of Greece	OPAP
Viohalko	Greek Telecommunication Company
Greek Electricity Company	Vodafone – Panafon
Coca – Cola	Pireaus Bank
Greek Petroleum	Titan Cement
Elliniki Technodomiki	Commercial Bank of Greece
Greek Bank of Industrial Development	National Bank of Greece
Eurobank	Intracom

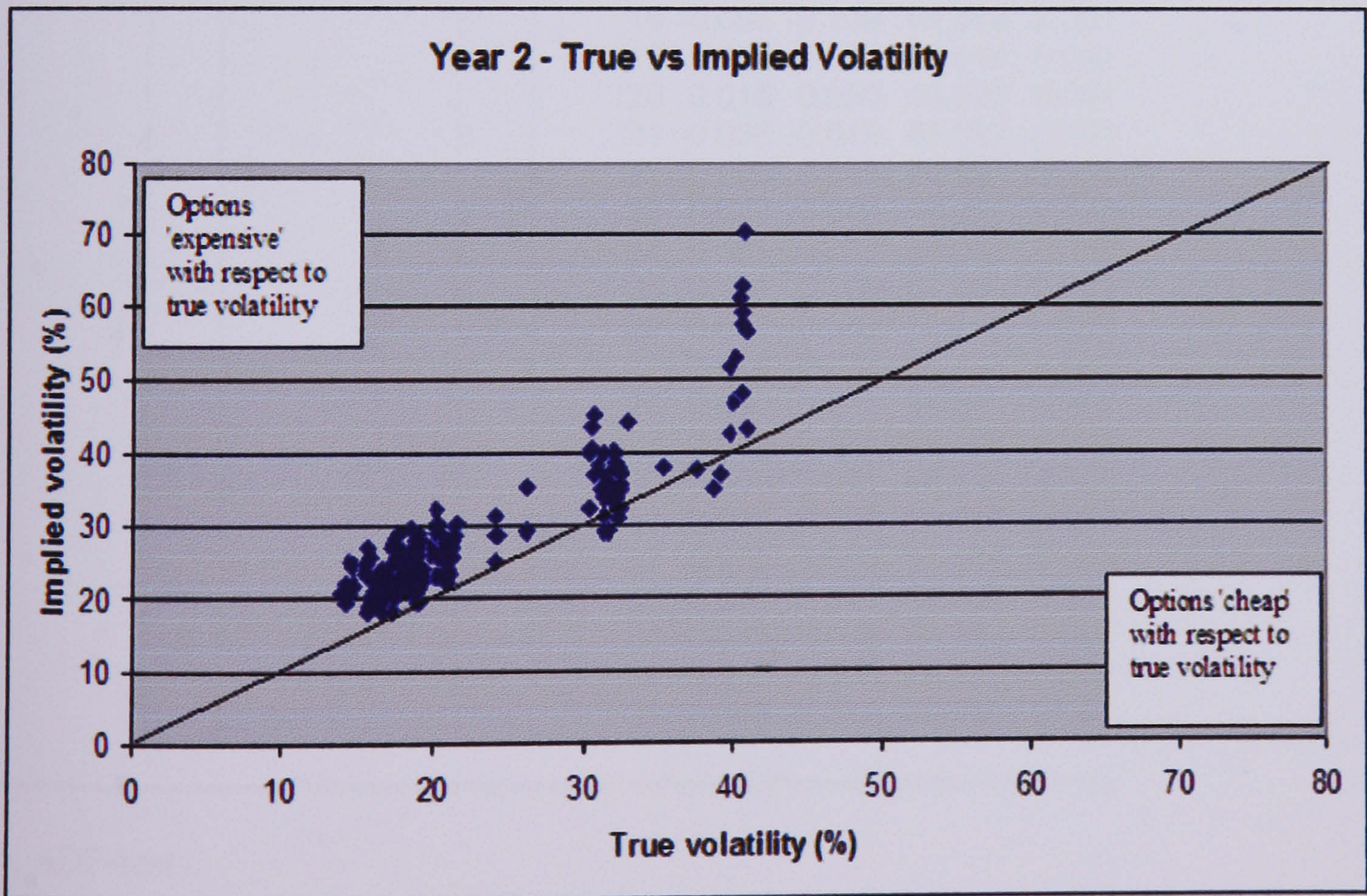
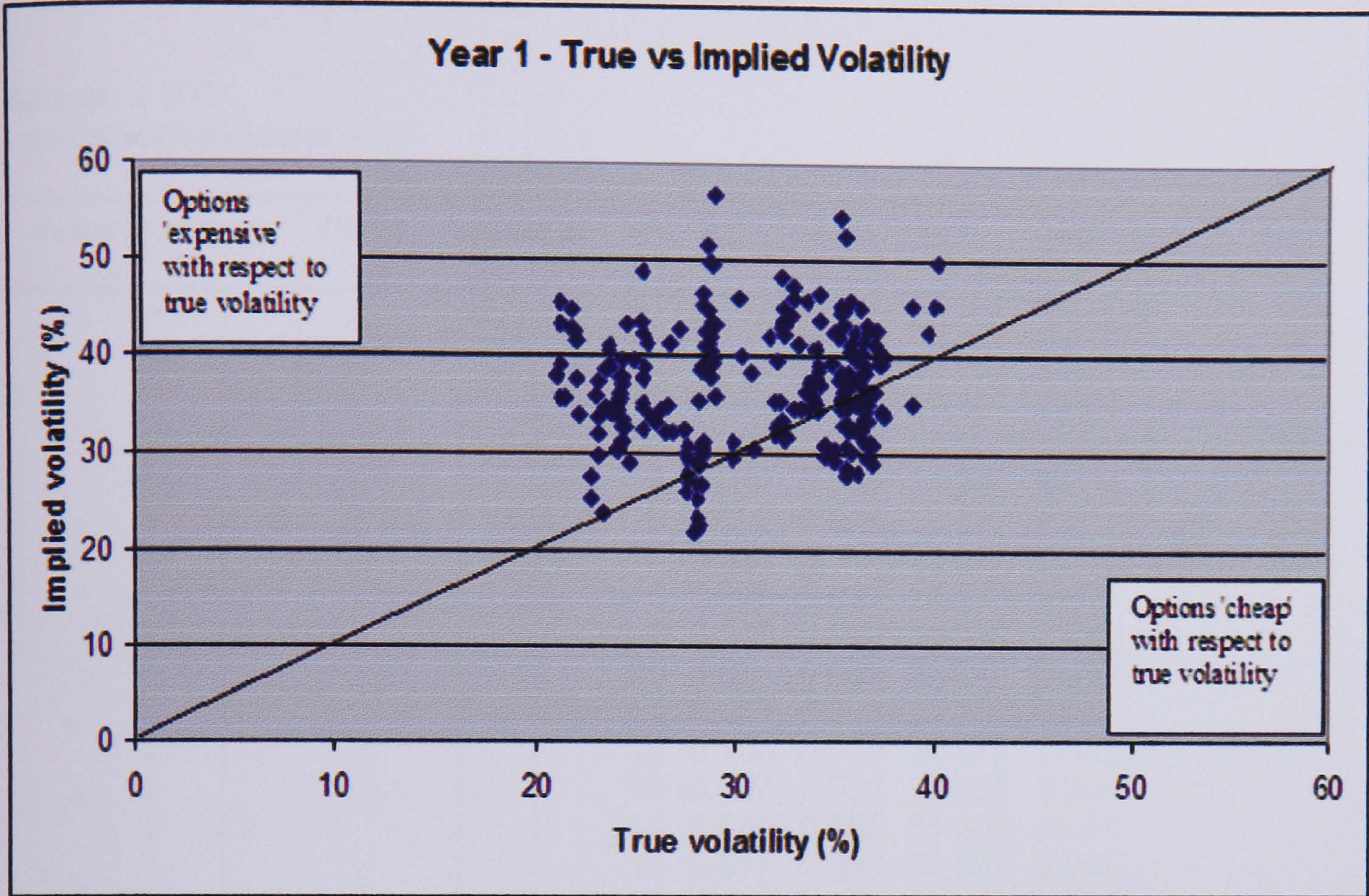
Appendix 5: Asymmetric information figure for 2000-2001 and 2001-2002



Appendix 6: Implied vs True volatility for 2000-2001 and 2001-2002



Appendix 7: True vs Implied volatility for 2000-2001 and 2001-2002



Appendix 8: Correlogram and ADF-test for Random – Walk regression’s residuals

a. Correlogram:

Sample: 1 500
 Included observations: 499

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
. *	. *	1	0.116	0.116	6.7552	0.009
* .	* .	2	-0.063	-0.078	8.7622	0.013
. *	. *	3	0.087	0.106	12.554	0.006
. *	. *	4	0.106	0.079	18.257	0.001
. .	. .	5	-0.044	-0.055	19.247	0.002
. .	. .	6	-0.022	-0.004	19.497	0.003
. .	. .	7	-0.020	-0.042	19.690	0.006
. .	. .	8	0.016	0.022	19.815	0.011
. .	. .	9	0.016	0.020	19.944	0.018
* .	* .	10	-0.081	-0.082	23.310	0.010
* .	. .	11	-0.061	-0.038	25.207	0.009
* .	* .	12	-0.105	-0.120	30.875	0.002
. .	. .	13	-0.007	0.026	30.902	0.003
. .	. .	14	0.044	0.056	31.909	0.004
. .	. .	15	0.017	0.028	32.051	0.006
* .	* .	16	-0.076	-0.063	35.045	0.004
* .	* .	17	-0.083	-0.099	38.575	0.002
* .	* .	18	-0.096	-0.109	43.414	0.001
. .	. .	19	-0.054	-0.031	44.914	0.001
. .	. .	20	0.015	0.050	45.025	0.001
. .	. .	21	-0.036	-0.019	45.692	0.001
. .	. .	22	0.050	0.059	46.991	0.001
. .	. .	23	0.003	-0.049	46.997	0.002
. .	. .	24	0.063	0.063	49.072	0.002
. *	. *	25	0.101	0.106	54.455	0.001
. .	. .	26	0.050	0.042	55.775	0.001
. .	. .	27	0.004	0.003	55.783	0.001
. .	* .	28	0.010	-0.071	55.841	0.001
. .	. .	29	0.024	-0.034	56.152	0.002
* .	* .	30	-0.069	-0.091	58.710	0.001
. .	. .	31	-0.018	0.022	58.886	0.002
* .	. .	32	-0.075	-0.053	61.912	0.001
. .	. .	33	-0.024	-0.011	62.210	0.002
. .	. .	34	-0.037	-0.045	62.937	0.002
. .	* .	35	-0.056	-0.066	64.626	0.002
. .	. .	36	-0.048	-0.010	65.885	0.002

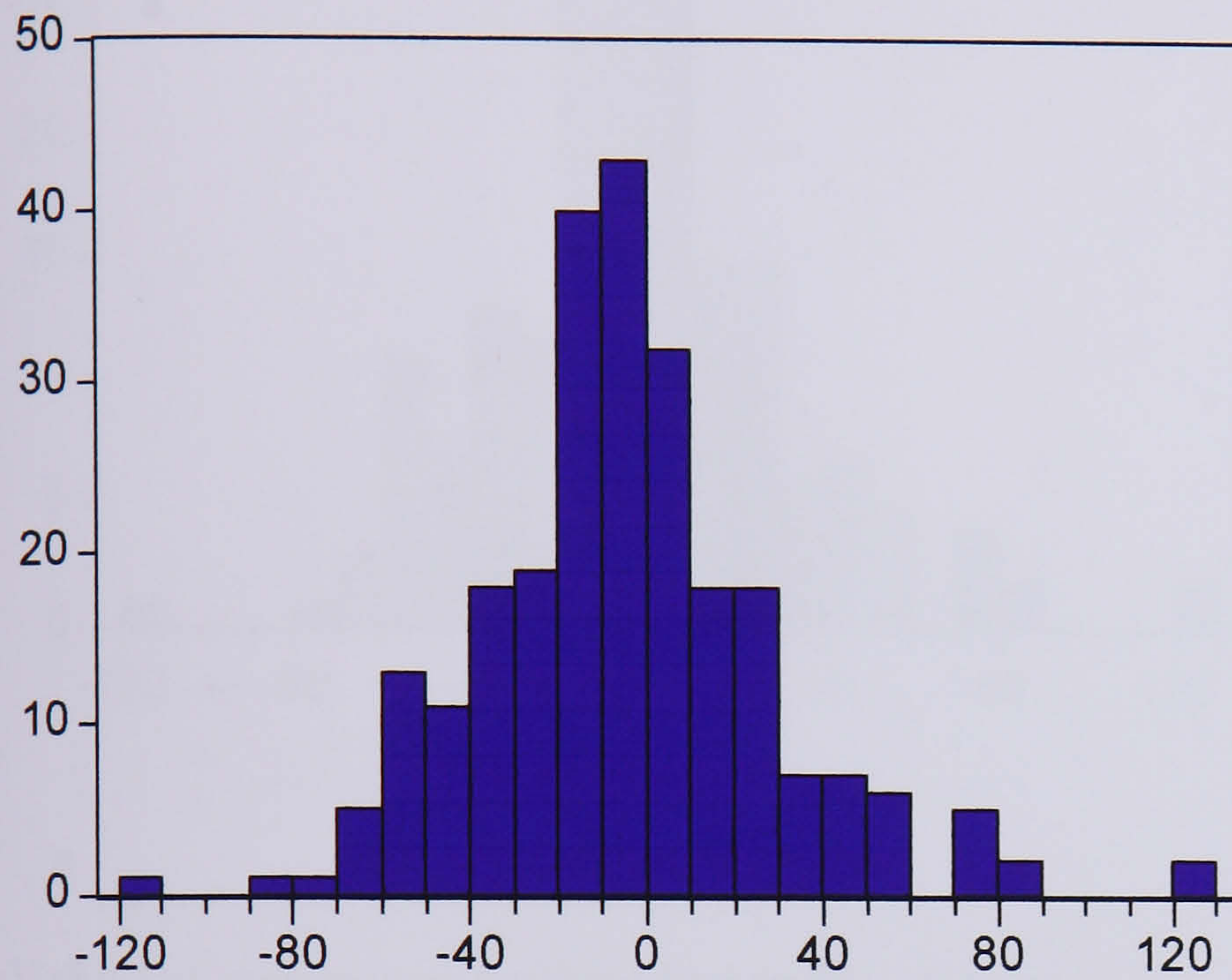
b. ADF-test:

ADF Test Statistic	-9.196321	1% Critical Value*	-3.9809
		5% Critical Value	-3.4208
		10% Critical Value	-3.1328

*Mackinnon critical values for rejection of hypothesis of a unit root.

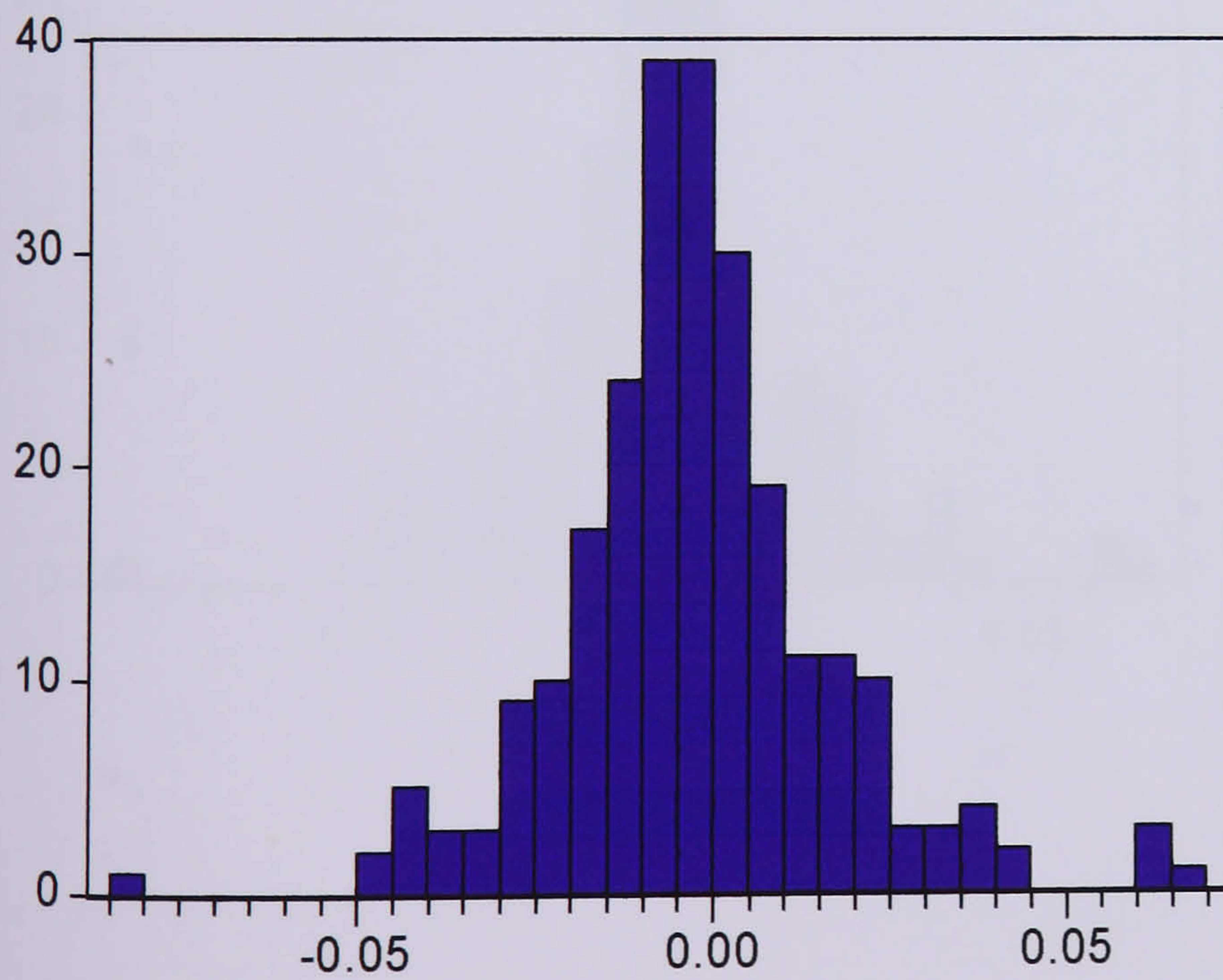
Appendix 9: Histograms and Descriptive Statistics for index and log-index prices for the years 2000-2001 and 2001-2002

a. Year 1: Index change



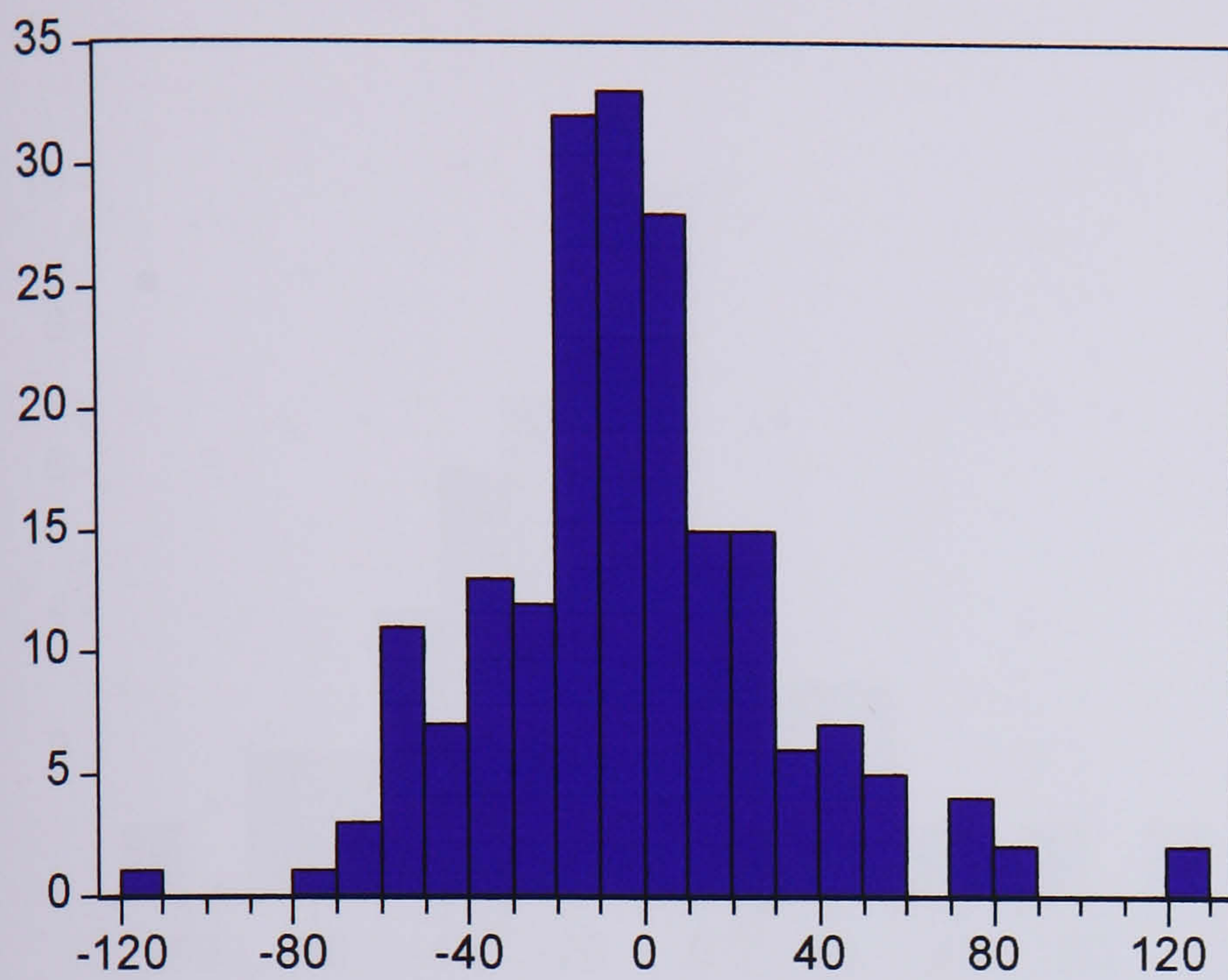
Series: YR1INDCHANGE	
Sample 2 250	
Observations 249	
Mean	-4.443735
Median	-6.390000
Maximum	127.7400
Minimum	-110.6400
Std. Dev.	33.28142
Skewness	0.606037
Kurtosis	4.850166
Jarque-Bera	50.75698
Probability	0.000000

b. Year 1: Log-index change



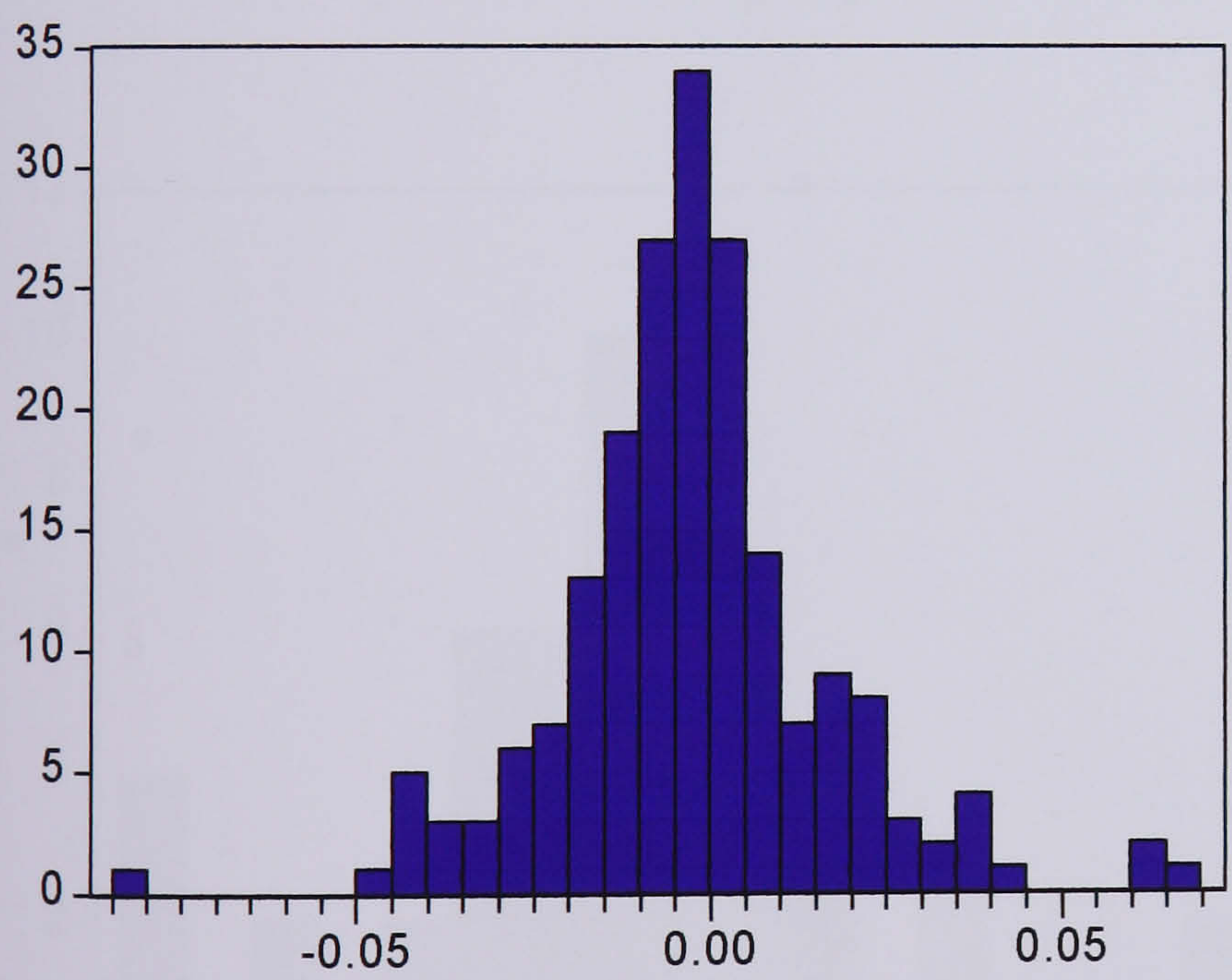
Series: YR1LINDCHANGE	
Sample 2 250	
Observations 249	
Mean	-0.002559
Median	-0.003628
Maximum	0.068380
Minimum	-0.080191
Std. Dev.	0.019192
Skewness	0.323974
Kurtosis	5.338364
Jarque-Bera	61.08572
Probability	0.000000

c. Year 1: Continuous trading index change



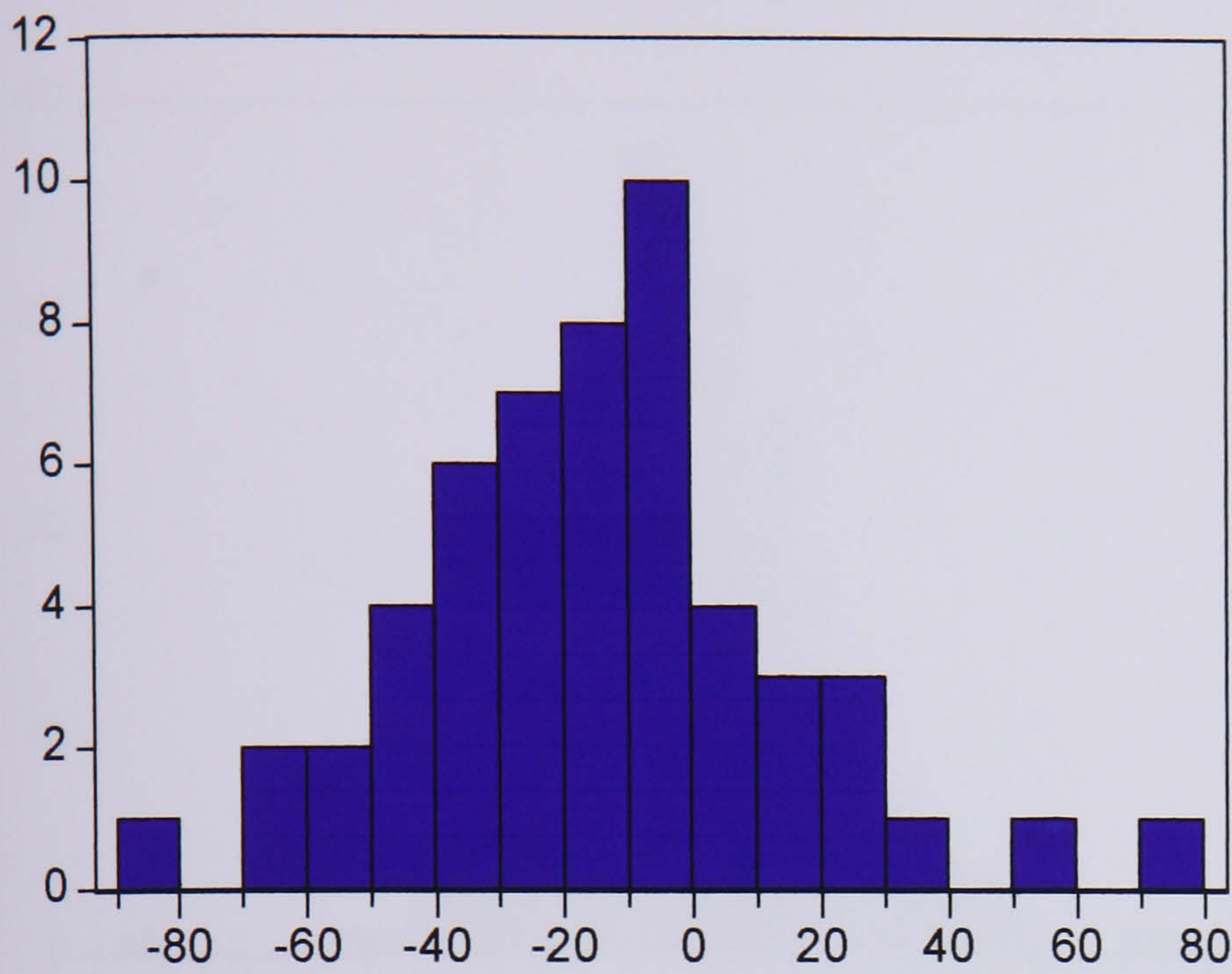
Series: YR1CONTTRAD	
Sample 1 197	
Observations 197	
Mean	-2.152893
Median	-4.640000
Maximum	127.7400
Minimum	-110.6400
Std. Dev.	33.76778
Skewness	0.631072
Kurtosis	4.996602
Jarque-Bera	45.79782
Probability	0.000000

d. Year 1: Continuous trading log-index change



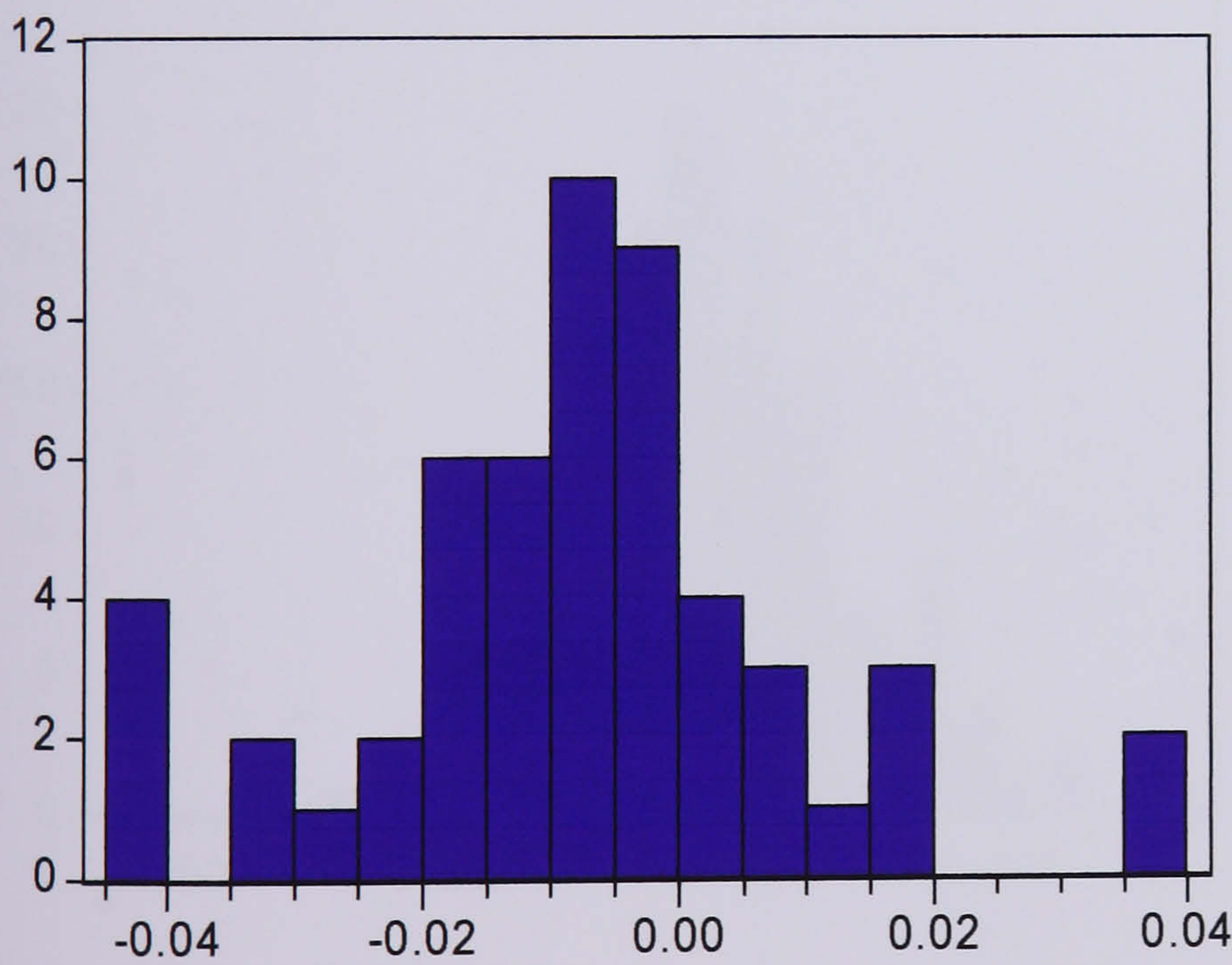
Series: YR1CONTTRADLOGS	
Sample 1 197	
Observations 197	
Mean	-0.002617
Median	-0.002601
Maximum	0.068380
Minimum	-0.080191
Std. Dev.	0.019456
Skewness	0.201173
Kurtosis	5.392186
Jarque-Bera	48.30143
Probability	0.000000

e. Year 1: Two-days break trading index change



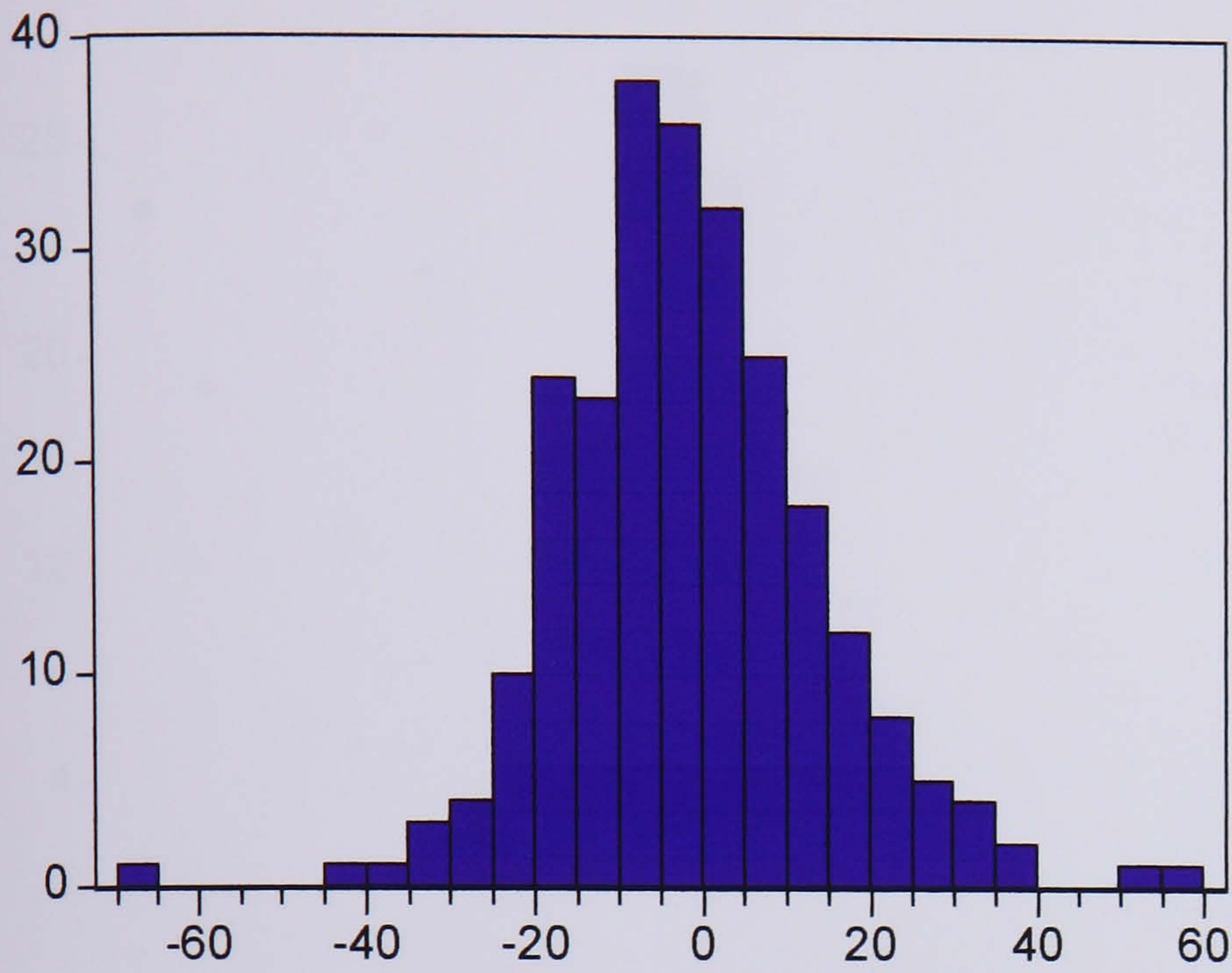
Series: YR1TDAYBR	
Sample 1 53	
Observations 53	
Mean	-13.54151
Median	-14.05000
Maximum	75.49000
Minimum	-80.32000
Std. Dev.	29.98069
Skewness	0.379528
Kurtosis	3.612416
Jarque-Bera	2.100606
Probability	0.349832

f. Year 1: Two-days break trading log-index change



Series: YR1TDAYBRLOGS	
Sample 1 53	
Observations 53	
Mean	-0.007650
Median	-0.007754
Maximum	0.038273
Minimum	-0.044392
Std. Dev.	0.017531
Skewness	0.105507
Kurtosis	3.680578
Jarque-Bera	1.121201
Probability	0.570866

g. Year 2: Index change

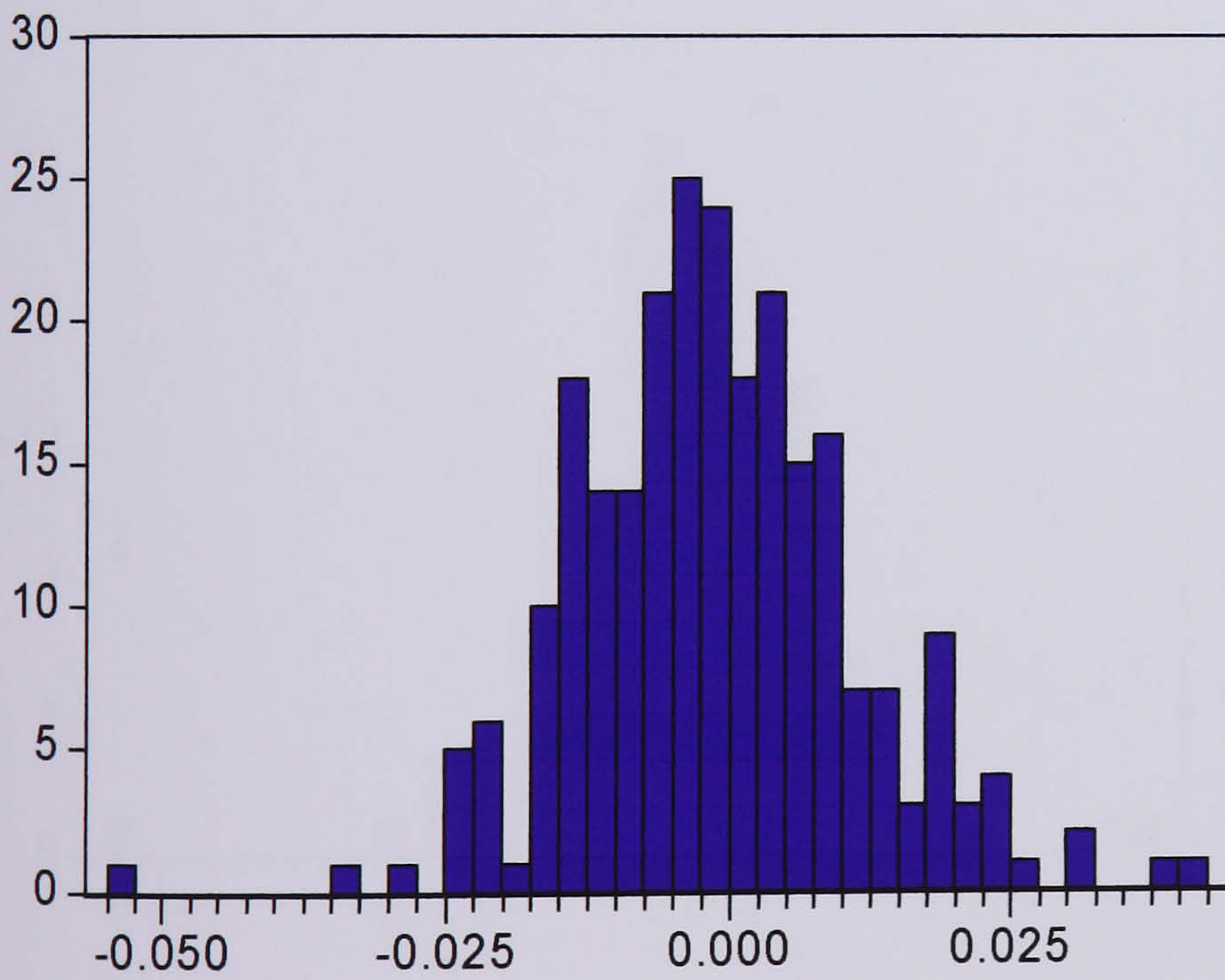


Series: YR2INDCHANGE
 Sample 252 500
 Observations 249

Mean -1.283534
 Median -2.190000
 Maximum 58.44000
 Minimum -66.35000
 Std. Dev. 15.61207
 Skewness 0.252357
 Kurtosis 4.802574

Jarque-Bera 36.35411
 Probability 0.000000

h. Year 2: Log-index change

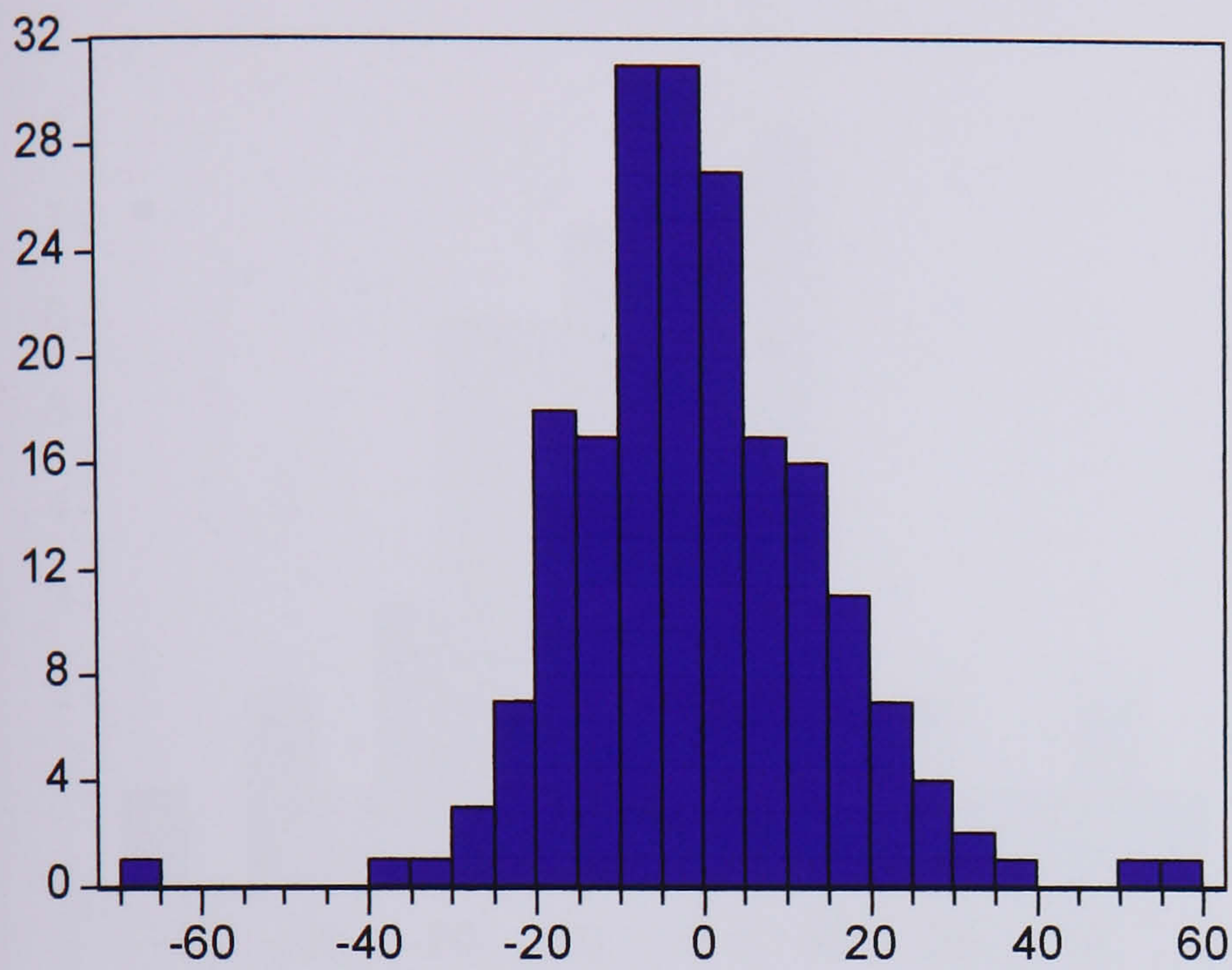


Series: YR2LINDCHANGE
 Sample 252 500
 Observations 249

Mean -0.001174
 Median -0.001818
 Maximum 0.041323
 Minimum -0.054037
 Std. Dev. 0.012438
 Skewness 0.129183
 Kurtosis 4.495361

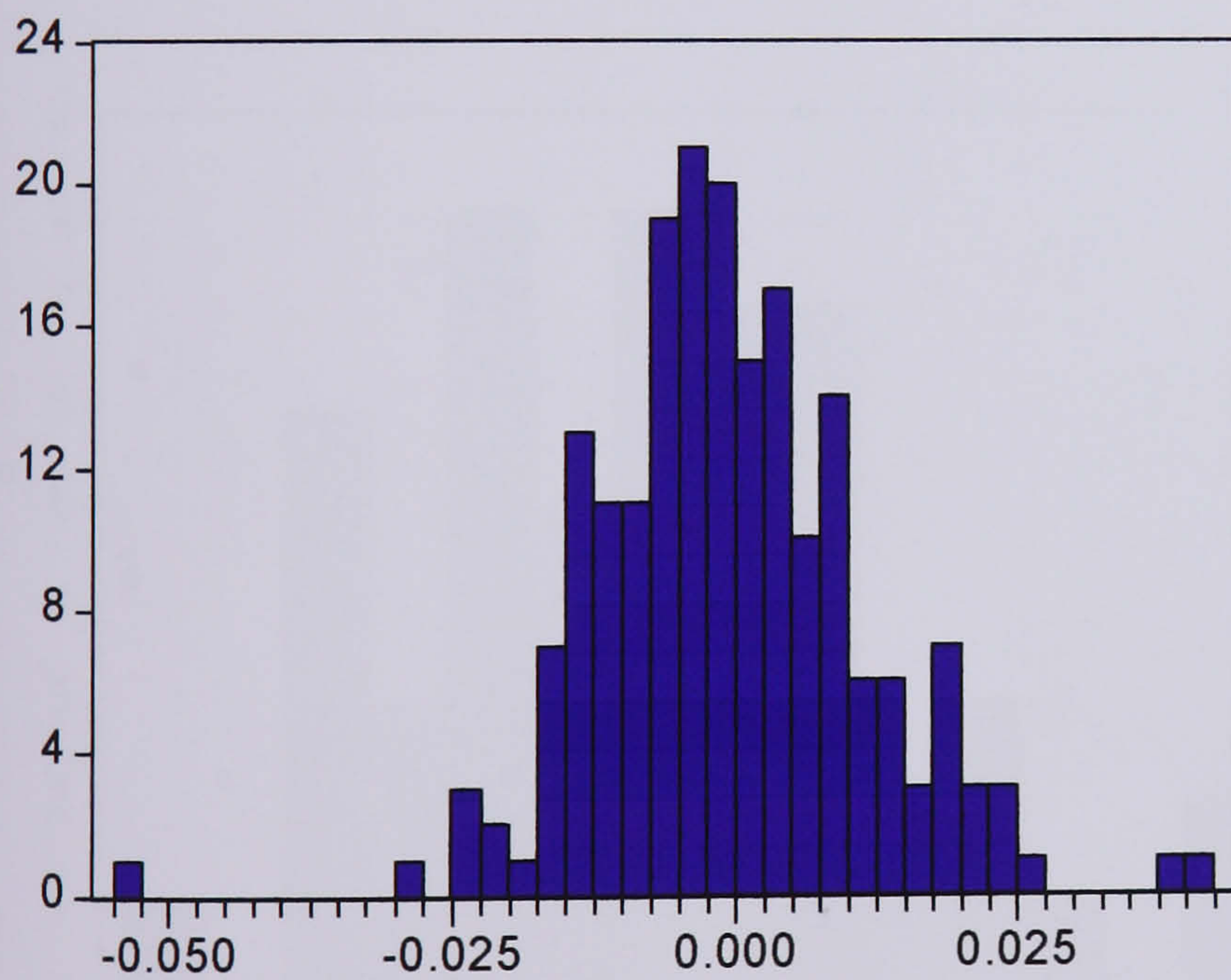
Jarque-Bera 23.89214
 Probability 0.000006

i. Year 2: Continuous trading index change



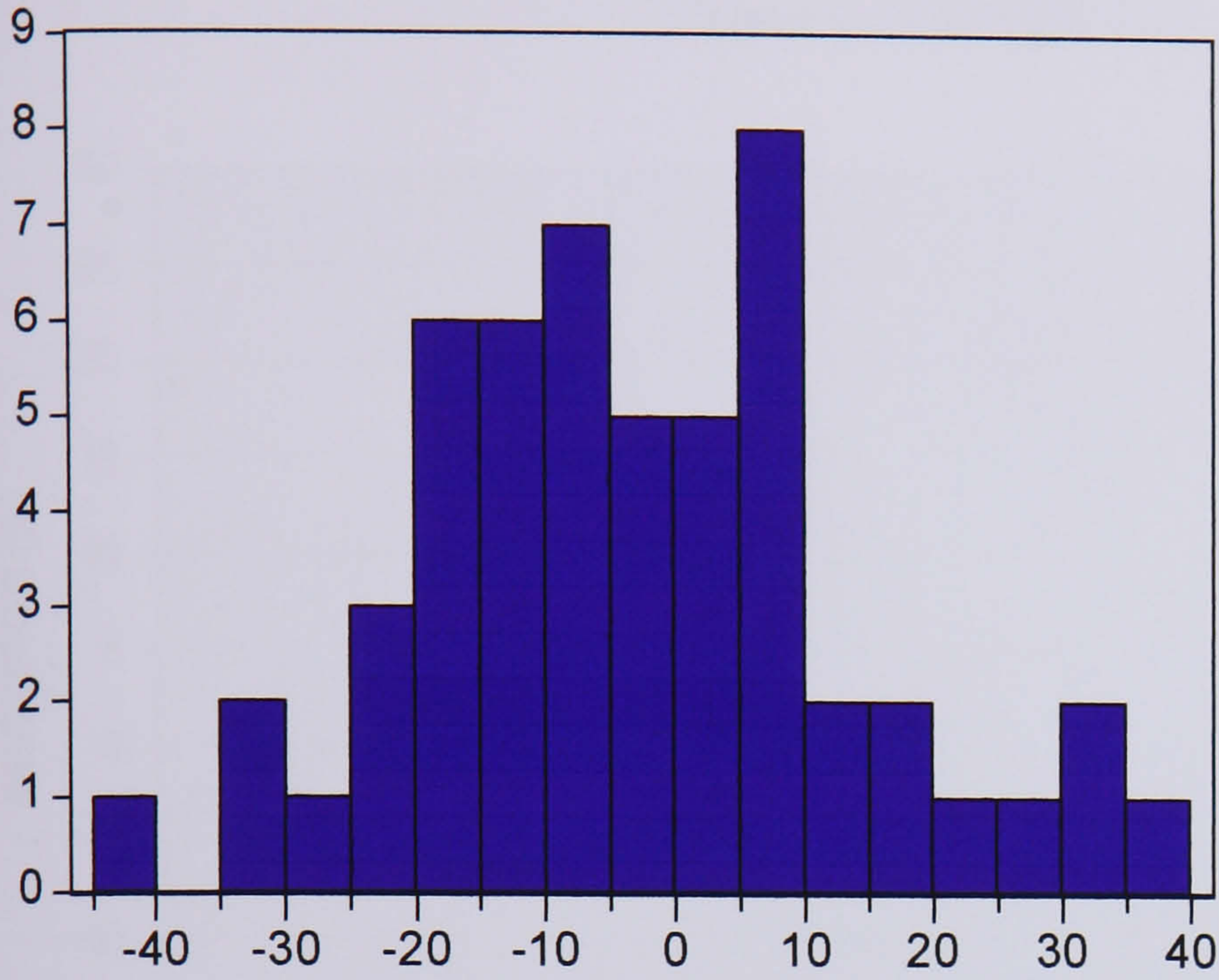
Series: YR2CONTTRAD	
Sample 1 197	
Observations 197	
Mean	-0.701777
Median	-1.840000
Maximum	58.44000
Minimum	-66.35000
Std. Dev.	15.22226
Skewness	0.282166
Kurtosis	5.548071
Jarque-Bera	55.90809
Probability	0.000000

j. Year 2: Continuous trading log-index change



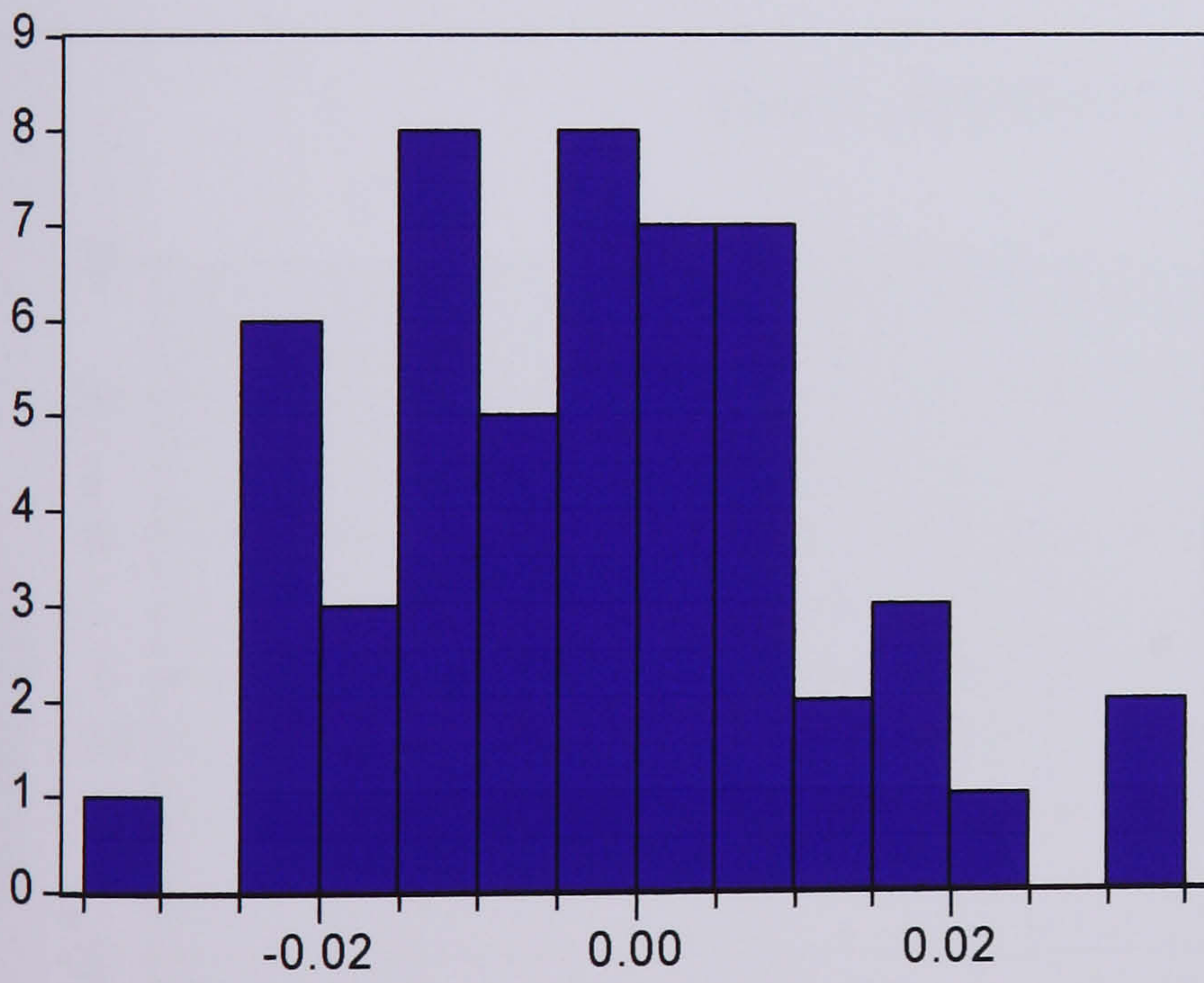
Series: YR2CONTTRADLOGS	
Sample 1 197	
Observations 197	
Mean	-0.000695
Median	-0.001461
Maximum	0.041323
Minimum	-0.054037
Std. Dev.	0.012021
Skewness	0.080144
Kurtosis	5.164371
Jarque-Bera	38.66285
Probability	0.000000

k. Year 2: Two-days break trading index change



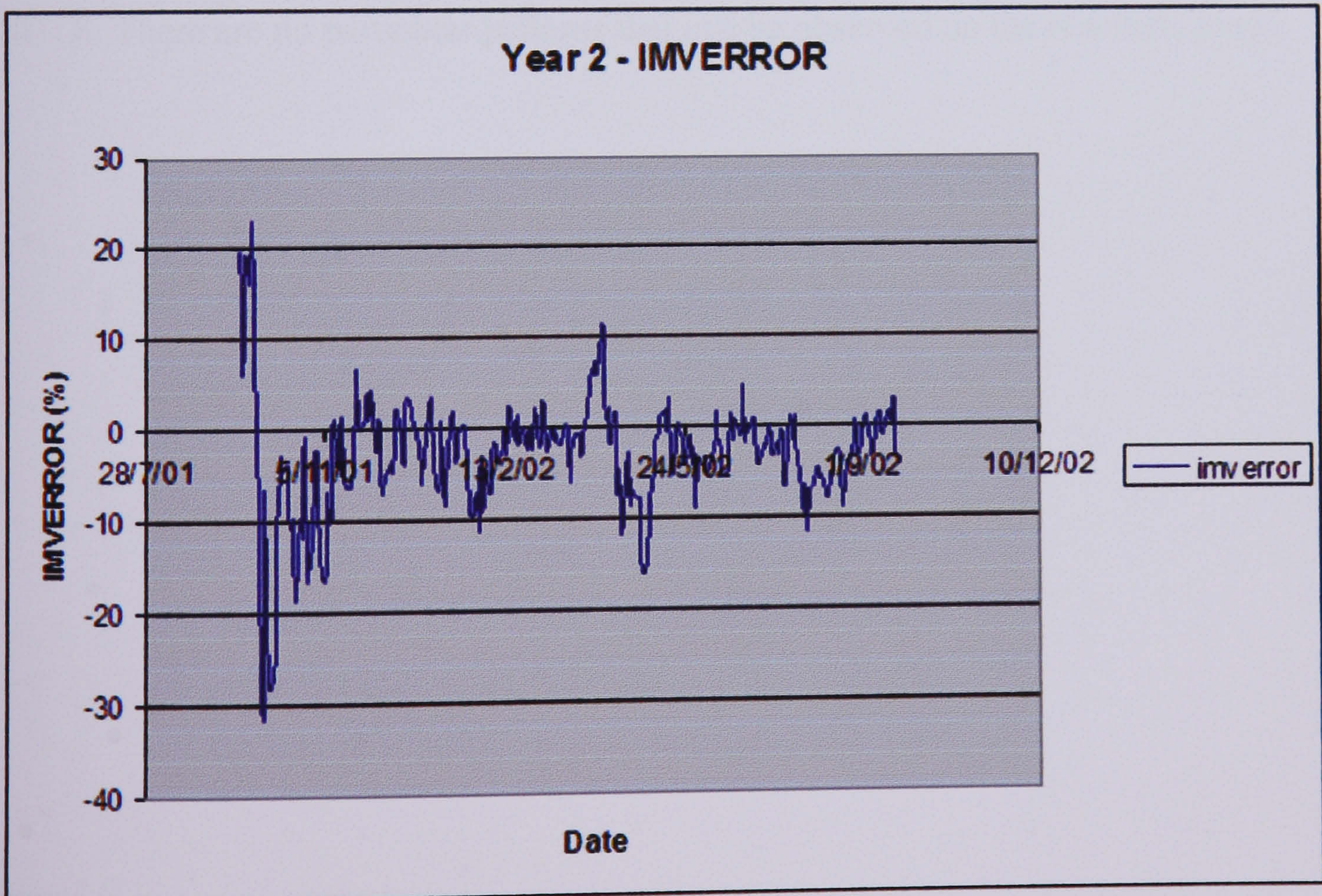
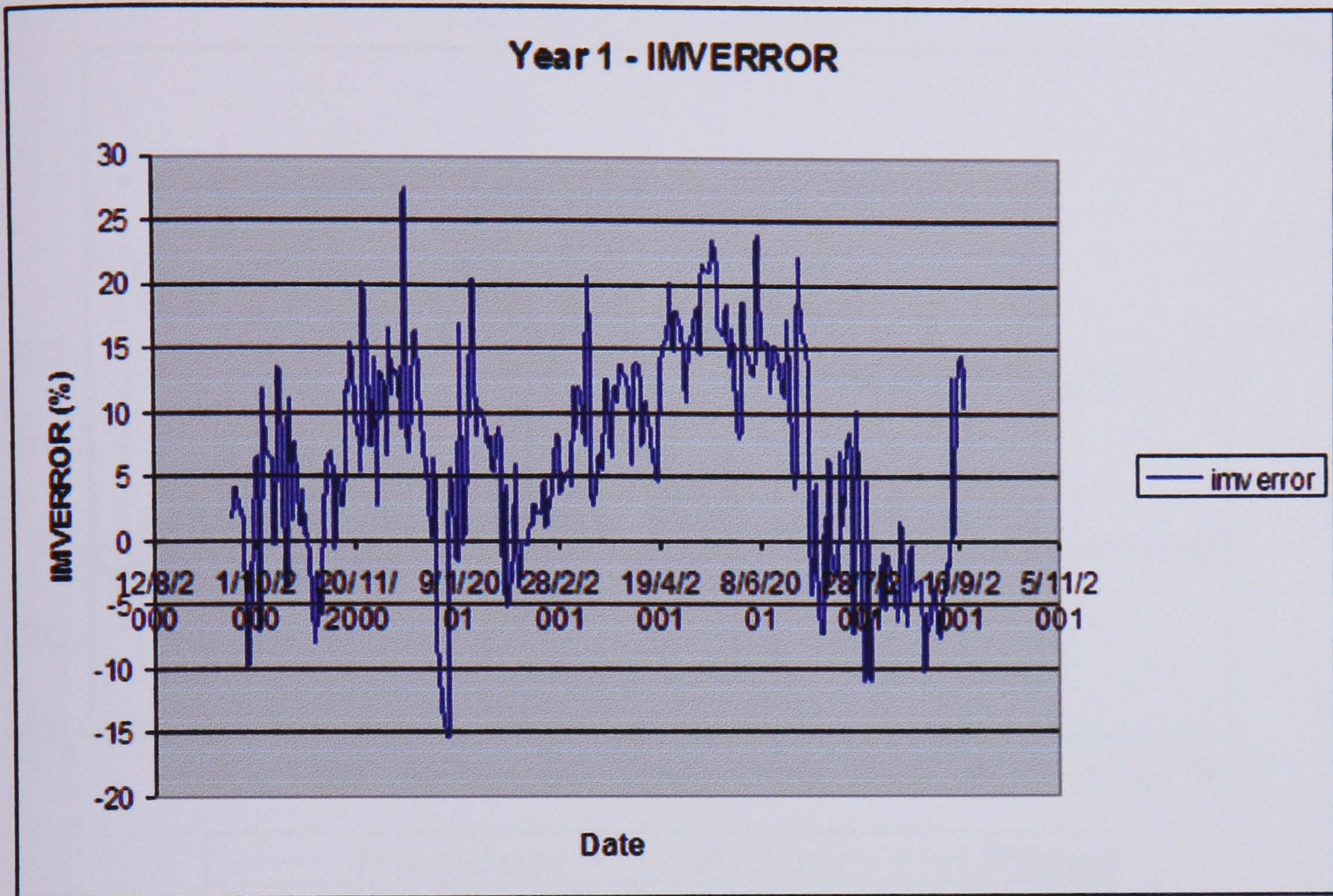
Series: YR2TDAYBR	
Sample 1 53	
Observations 53	
Mean	-3.050755
Median	-3.410000
Maximum	35.58000
Minimum	-41.62000
Std. Dev.	17.11754
Skewness	0.209209
Kurtosis	2.768223
Jarque-Bera	0.505256
Probability	0.776757

l. Year 2: Two-days break trading log-index change

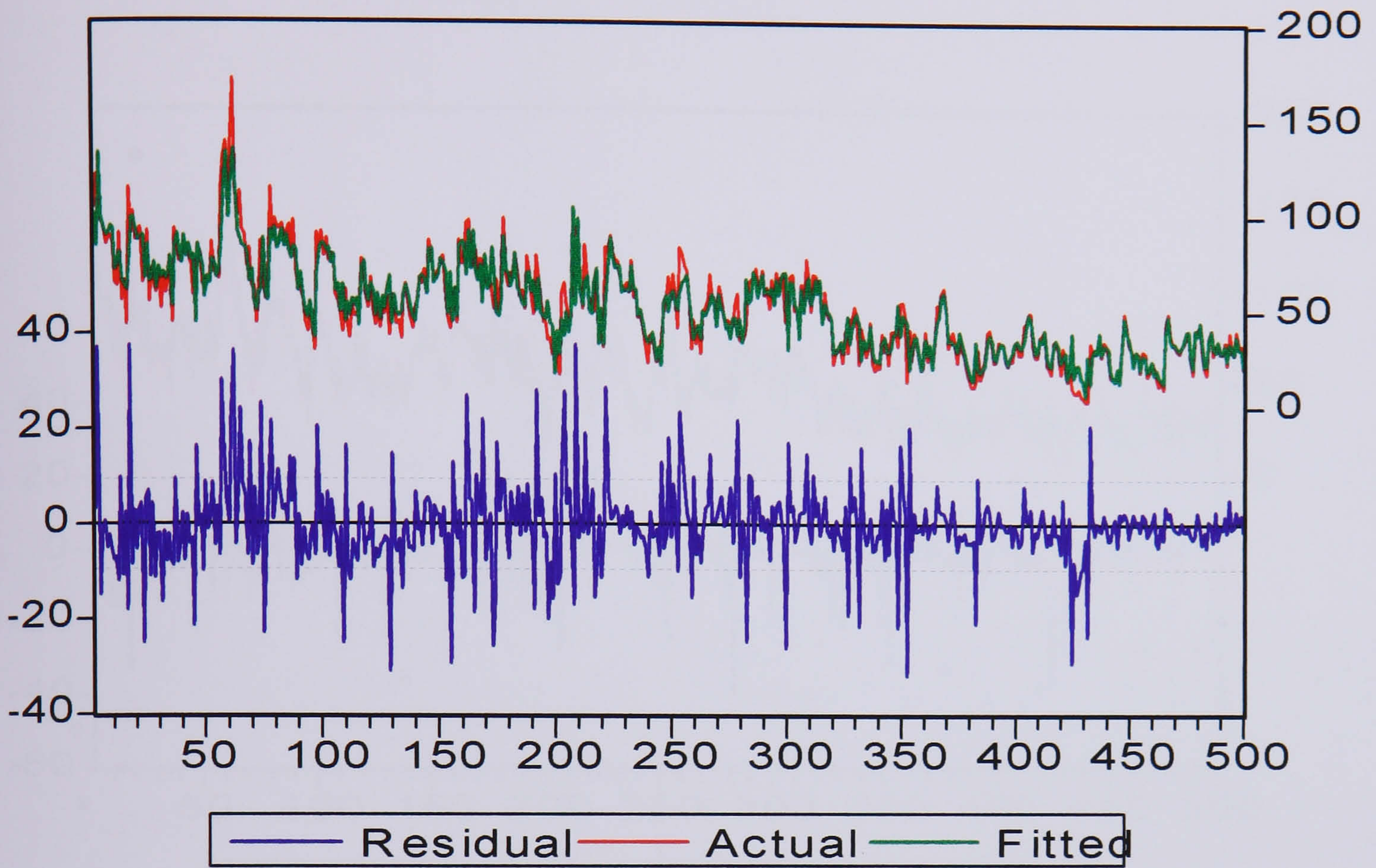


Series: YR2TDAYBRLOGS	
Sample 1 53	
Observations 53	
Mean	-0.002633
Median	-0.003107
Maximum	0.030937
Minimum	-0.034446
Std. Dev.	0.013984
Skewness	0.306265
Kurtosis	2.898457
Jarque-Bera	0.851322
Probability	0.653338

Appendix 10: Call and Put implied volatilities for the years 2000-2001 and 2001-2002

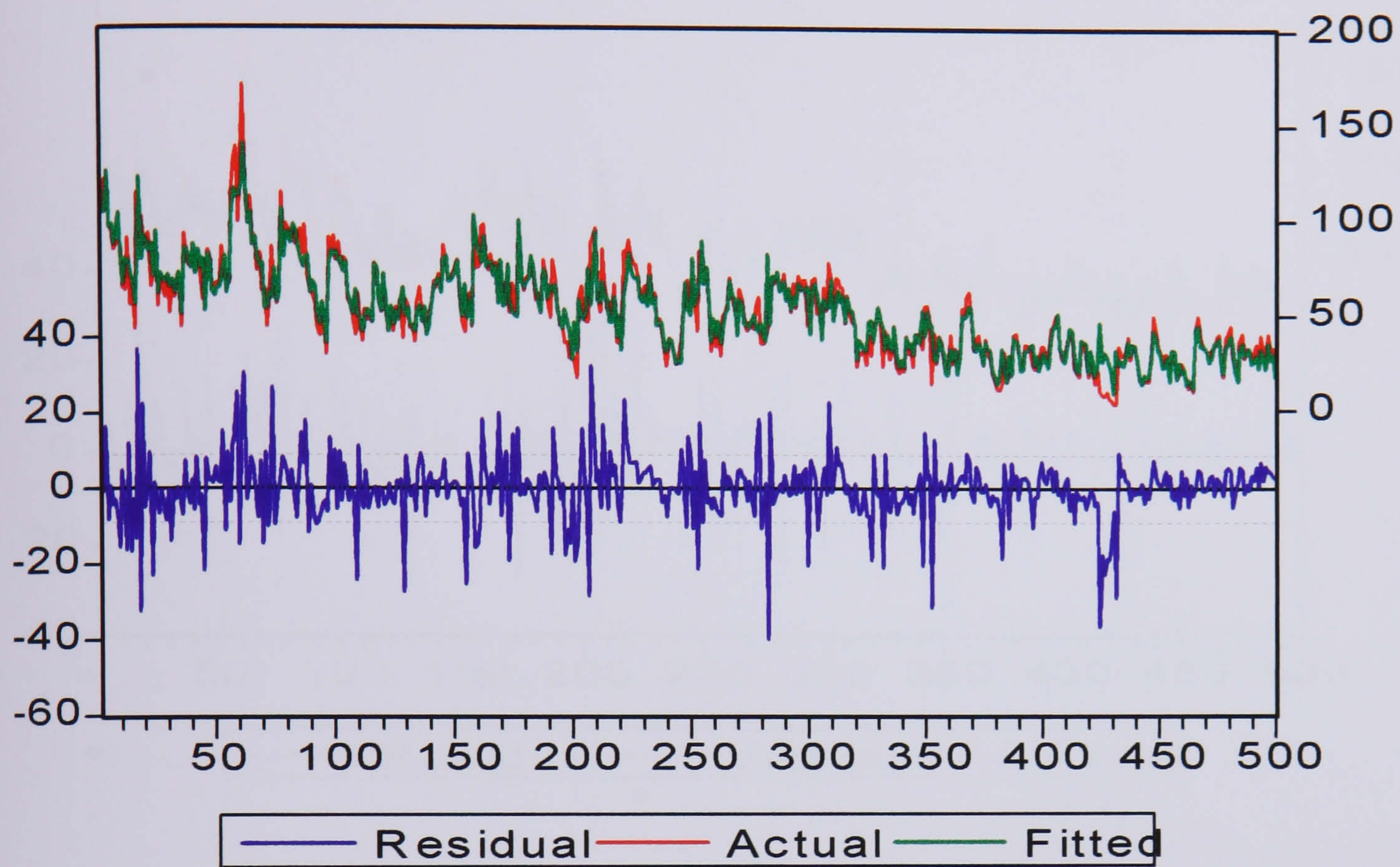


Appendix 11: Model 1: fitted values and residuals' plot

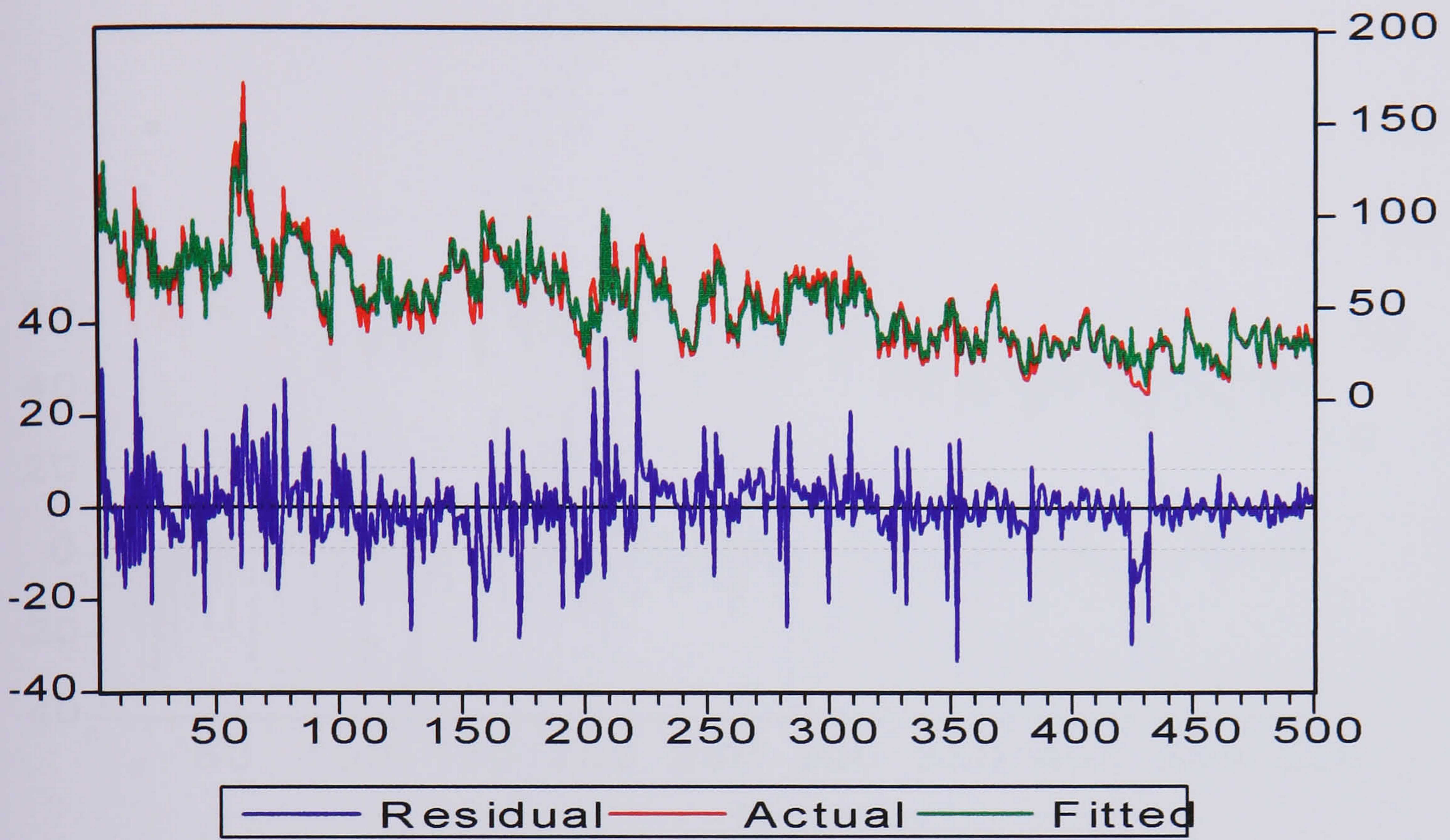


NOTE: There are no particular patterns that can be observed on the residuals graph

Appendix 12: Model 2: fitted values and residuals' plot

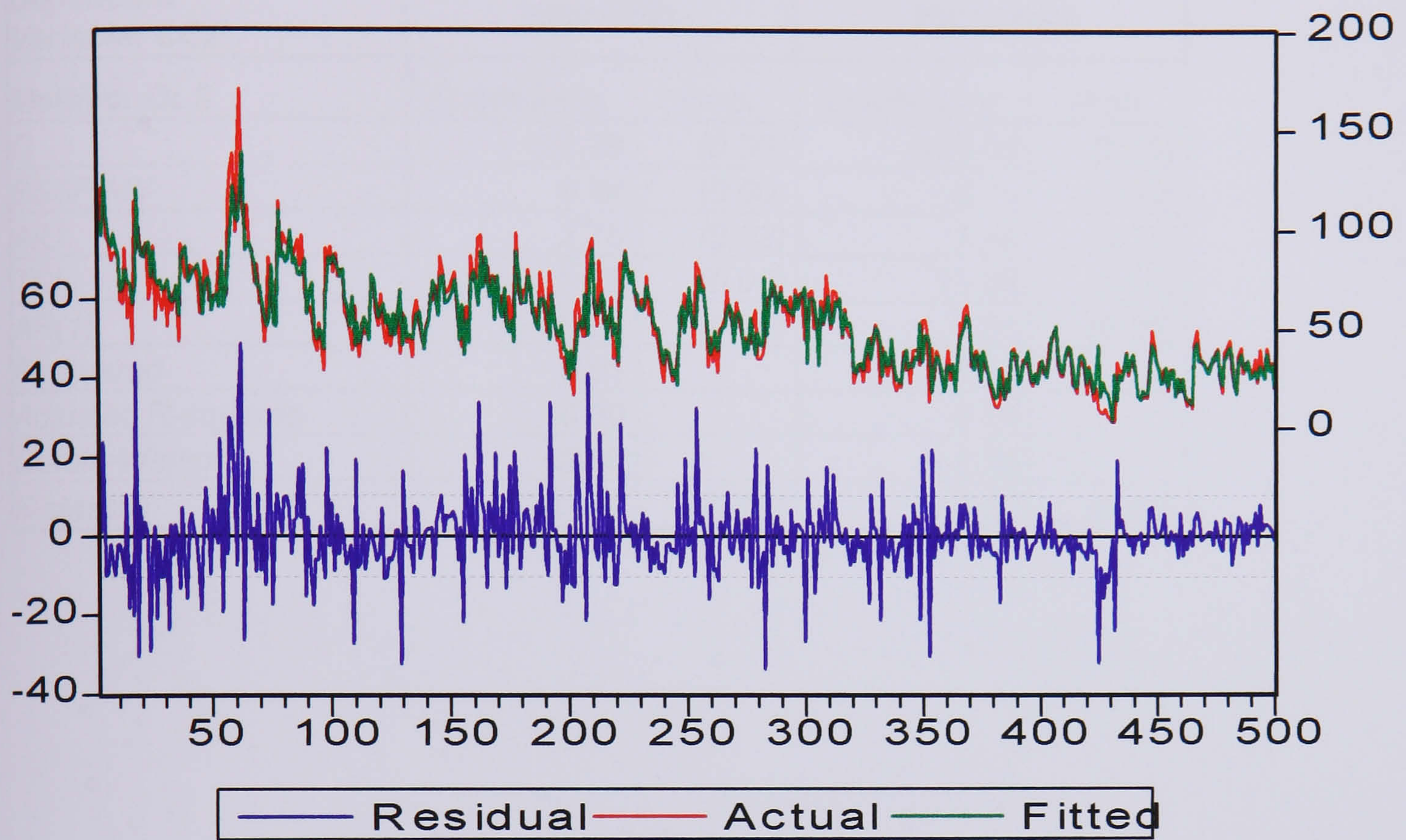


NOTE: There are no particular patterns that can be observed on the residuals graph

Appendix 13: Model 3: fitted values and residuals' plot

NOTE: There are no particular patterns that can be observed on the residuals graph

Appendix 14: Model 4: fitted values and residuals' plot



NOTE: There are no particular patterns that can be observed on the residuals graph

Appendix 15: Model 4 regression results for the two years individually

Dependent Variable: COP	2000-2001		2001-2002	
Method: OLS	<i>Coefficients:</i>	<i>Prob.</i>	<i>Coefficients:</i>	<i>Prob.</i>
<i>C</i>	-88.98	(0.00)	-162.93	(0.00)
<i>BSSPIMV</i>	0.98	(0.00)	0.74	(0.00)
<i>AIU</i>	2.75	(0.23)	7.46	(0.27)
<i>TCI</i>	6.25	(0.00)	11.68	(0.00)
<i>AR(1)</i>	0.25	(0.00)	0.56	(0.00)
<i>R-squared</i>	0.81		0.79	
<i>Adjusted R-squares</i>	0.80		0.79	
<i>Durbin-Watson</i>	2.06		2.28	
<i>F-statistic</i>	263.22	(0.00)	240.29	(0.00)

List of Abbreviations

ADECH = Athens Derivatives Clearing House

ADEX = Athens Derivatives Exchange

ADF = Augmented Dickey Fuller

AID = Asymmetric Information causing the index to fall

AIN = No Asymmetric Information

AIU = Asymmetric Information causing the index to rise

AMEX = Amsterdam Stock Exchange

APT = Arbitrage Pricing Theory

AR = Autoregressive Error Term

ARCH = Autoregressive Conditional Heteroscedasticity

ASE = Athens Stock Exchange

BSOPM = Black and Scholes Option Pricing Model

BSFPIMV = BSOPM theoretical prices which are calculated based on the future index and implied volatility

BSFPTV = BSOPM theoretical prices which are calculated based on the future index and true volatility

BSSPIMV = BSOPM theoretical prices which are calculated based on the spot index and implied volatility

BSSPTV = BSOPM theoretical prices which are calculated based on the spot index and true volatility

CALLIMV = Call Option Implied Volatility

CAPM = Capital Asset Pricing Model

CBOE = Chicago Board Options Exchange

CEO = Chief Executive Officer

COP = Actual Call Option Prices

DAX = Deutsche Aktienindex i.e. German's Stock Exchange high capitalisation index

DW = Durbin-Watson

EMH = Efficient Market Hypothesis

EOE = European Options Exchange

EU = European Union

- FTSE/ASE 20 = Greek's stock exchange high capitalisation index
- GARCH = Generalised Autoregressive Conditional Heteroscedasticity
- IMV = Implied Volatility
- IND = FTSE/ASE 20 index
- ITV = Index's transaction volumes
- JB = Jarque-Bera
- LIFFE = London International Financial Futures and Options Exchange
- LTOM = London Traded Options Market
- MRIND = Monthly Return of the FTSE/ASE 20 index
- NASDAQ = National Association of Securities Dealers Automated Quotation system
- NYSE = New York Stock Exchange
- OLS = Ordinary Least Squares
- OTV = Option transaction volumes
- PUTIMV = Put Option Implied Volatility
- RIND = Daily Return of the FTSE/ASE 20 index
- RMSE = Root Mean Square Error
- S&P = Standard and Poor
- TCF = Transaction costs for future prices
- TCI = Transaction costs for spot prices
- TSE = Tokyo Stock Exchange
- TV = True Volatility
- WISD = Weighted Implied Standard Deviation
- WSE = Warsaw Stock Exchange

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