

INSTITUTE OF TECHNOLOGY BLANCHARDSTOWN

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# Predictions in Financial Time Series Data

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*A thesis submitted in partial fulfilment of the requirements  
for the degree of Master of Science in Computing*

*from the*

School of Informatics and Engineering

August 2014

# Declaration of Authorship

I, Dr. Allan STEEL, declare that this thesis titled, 'Predictions in Financial Time Series Data' and the work presented in it are my own. I confirm that:

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- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
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## *Abstract*

School of Informatics and Engineering

Master of Science in Computing

### **Predictions in Financial Time Series Data**

by Dr. Allan STEEL

For hundreds of years speculators have tried to make a profit from the financial markets by predicting their future movements. To this end, many methods and techniques have been developed that purport to assist the market participant in generating profits. This study reports on the effectiveness of several such techniques to help predict the one step ahead forecasts of a range of national stock market indices (DAX, FTSE, CAC, Dow Jones, Nikkei and AORD) . A selection of technical analysis indicators as well as more traditional time series prediction models such as exponential smoothing, ARIMA and hybrid ARIMA techniques are explored. Results from the predictive models are passed to trading algorithms where purchasing decisions are directed by the forecasts. Profitable systems are developed based on predictions from technical analysis and hybrid ARIMA models using a k-NN learner.

# *Acknowledgements*

I wish to thank my supervisor Dr Geraldine Grey for her guidance, support and patience throughout the completion of this project. I would also like to acknowledge Dr Markus Hofmann and Laura Keyes, who along with Geraldine provided two years of stimulating and enjoyable lectures.

This study made extensive use of open source software and I would like to thank and acknowledge all the people who provided their time, skill and expertise to make world class software freely available.

Finally, I would like to thank my partner Ann for all her patience and help during the writing of this thesis.

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# Chapter 1

## Introduction

### 1.1 Background

For hundreds of years speculators have tried to make a monetary profit in financial markets by predicting the future price of commodities, stocks, foreign exchange rates and more recently futures and options. Over the last few decades these efforts have increased markedly, using a variety of techniques (Hsu, 2011), which can be broadly classified into three categories:

- fundamental analysis
- technical analysis
- traditional time series forecasting

#### 1.1.1 Fundamental Analysis

Fundamental analysis makes use of basic market information in order to predict future movements of an asset. If an investor was looking at a particular stock's fundamental data they would consider information such as revenue, profit forecasts, supply, demand and operating margins etc. Speculators looking at commodities might consider weather patterns, political aspects, government legislation and so on. Effectively fundamental analysis is concerned with macro economic and political factors that might affect the future price of a financial asset. Fundamental analysis is not considered further in this study.

### 1.1.2 Technical Analysis

Technical analysis is the study of historical prices and patterns with the aim of predicting future prices. Practitioners of technical analysis in the past were referred to as chartists, as they believed all that was needed to know about a particular market was contained in its pricing chart. Murphy (1999) defines technical analysis as:

*“Technical analysis is the study of market action, primarily through the use of charts for the purpose of forecasting future price trends.”*

Technical analysis (TA) is interesting as it tends to polarise opinion as to its scientific basis and effectiveness. To many people and particularly scholars in academia it is considered little more than Black Magic. Consider the words of Malkiel (1999):

*“Obviously I am biased against the chartist. This is not only a personal predilection, but a professional one as well. Technical Analysis is anathema to the academic world. We love to pick on it. Our bullying tactics are prompted by two considerations: (1) the method is patently false; and (2) it’s easy to pick on. And while it may seem a bit unfair to pick on such a sorry target, just remember: it is your money we are trying to save.”*

However, in the world of finance technical analysis is ubiquitous and widely used (Menkhoff, 2010). In support of TA a plethora of so-called indicators have been developed over the years from simple moving averages to much more exotic offerings. Today every piece of software or on-line analysis tool provides the ability to place a multitude of technical indicators on a graph of a stock, commodity or any financial instrument.

Most technical indicators essentially fall into one of two main categories, ones attempting to detect the start and direction of trends and those trying to identify market reversals generally called oscillators. Trend analysis indicators include Average Direction Index (ADX), Aroon, Moving Averages and Commodity Channel Indexes (CCI). Price oscillator indicators include, Moving Average Convergence Divergence (MACD - (Appel and Dobson, 2007)), Stochastics, Relative Strength Index (RSI) and the Chande Momentum Oscillator (CMO).

### 1.1.3 Time Series Forecasting

The study of forecasting time series data has been an active area of study for several decades (De Gooijer and Hyndman, 2006). Series data is ordered such that the ordering is an important if not critical aspect of the data, with the requirement to maintain this ordering enforcing certain requirements on any processing. Series data can be ordered by

factors such as distance or height but typically time is the ordering encountered. Financial data is an important category of series data and a variety of well known time series forecasting methods have been applied to the problem of predicting price movements in the financial markets. These have included, exponential smoothing, auto-regressive moving average (ARMA) and auto-regressive integrated moving average (ARIMA).

A variety of smoothing algorithms have been applied to series data in general and financial data in particular. Moving averages, including simple, weighted and exponential, are widely employed by participants in financial markets to both predict future movements and quantify current conditions. Classical time series analysis such as so-called Holt-Winters exponential smoothing, the auto-regressive moving average (ARMA or Box-Jenkins model) and auto-regressive integrated moving average (ARIMA) methods have also been widely employed. In more recent years data mining techniques have been applied to the problem of financial time series prediction, for example with the use of artificial neural networks (ANNs) and support vector machines (SVM) as well as an hybrid approach of combining the classic time series techniques with the data mining methods in an attempt to leverage the strengths of each technique.

## 1.2 Statement of the Problem

The problem under study in this thesis is that of predicting the movement of financial markets. Financial markets include:

- Indices e.g. Dow Jones Index, FTSE 100 etc.
- Commodities e.g. gold, oil etc.
- Foreign exchange rates (also known as Forex or FX) e.g. GBP USD (price of British pounds divided by US dollars).
- Stocks e.g. Google, Apple, Barclays Bank etc.

The goal of financial traders is to detect the movement of the markets and buy instruments expected to rise in price “going long” and sell those predicted to fall in price “going short”. The markets are a neutral sum process, for every participant who gains there are those who lose.



## 1.3 Purpose of Study

The purpose of this study is to investigate and establish the usefulness and accuracy of a selection of technical indicators and time series analysis on the ability to predict future data movements in a group of national indice data sets.

### 1.3.1 Study Objectives

The objective of this study is three fold:

1. To investigate a group of national indice data sets in terms of their behaviour and characteristics.
2. To determine if a group of popular and widely used technical indicators can be used to predict the direction of movement in a range of financial markets.
3. To investigate if traditional time series models can predict the direction of movement in a range of financial markets.

## 1.4 Research Question

The research question addressed in this study is:

*“Can the use of technical indicators or time series analysis help to predict the future direction and movement of financial markets?”*

## 1.5 Methodology

The following methodology was used to answer the research question:

1. The current research in the field was reviewed.
2. Appropriate data was collected, primarily from freely available sources on the internet such as Yahoo and Google.
3. Initial data investigations and visualisations were carried out on the data.
4. Based on initial analysis, “base line” systems were established that could be used to compare the performance of systems generated by technical analysis and time series modelling.

5. A number of trading algorithms were generated that consumed the output of technical analysis indicators to determine in which direction to trade the financial data at any one time.
6. Times series modelling methods were used to generate forecasts for the financial data, and these were used in trading algorithms to decide in which direction, long or short, to trade.

## 1.6 Limitations of the Study

Limitations in this study include:

1. Choice of technical indicators - a small selection of the huge number available was selected. The selected group represent widely used examples and are drawn from the various categories available.
2. Use of financial data relating to stock market indices - daily data in the form of open, high, low and close prices (OHLC) from national stock market indices such as the Dow Jones or FTSE 100 is readily and freely available and thus was used in this study. High quality data in time frames other than daily or from alternative financial markets such commodities or foreign exchange is generally only commercially available and beyond the resources of this study.

## 1.7 Scope of the Study

There is a huge choice of financial data sets from which to choose and likewise many dozens of technical indicators. Given the time frame and resources available, this study employed daily data from major national indices such as the German DAX, US Dow and Japanese Nikkei. Technical indicators selected included examples from the primary categories such as trend detection and market reversal indicators.

## 1.8 Structure of Project

Chapter 2 is a literature review and introduction to financial market trading, the methods and theory of technical analysis and time series modelling. Financial trading systems in general are discussed along with the use and applicability of technical analysis. The classical time series methods of Holt-Winters exponential smoothing, auto-regressive

moving average (ARMA or Box-Jenkins model) and auto-regressive integrated moving average (ARIMA) are introduced and explained along with more recent developments such as hybrid ARIMA models.

Chapter 3 introduces the methodology used in this study. It includes a description of the data sets employed, software and programming languages utilised and the general approach taken. Chapter 4 details the experiments carried out using a variety of technical analysis indicators and lists the results from the trading algorithms generated. Chapter 5 documents the experimental work based on the use of time series modelling to generate forecasts for the financial data sets.

Chapter 6 is an analysis of the results obtained in Chapters 4 and 5 along with conclusions and suggestions for future work. Appendix A lists all the R programming code used in study. Wherever possible this report has the analysis generated by R programming code embedded into it. Thus, all trading algorithms coded in R detailed in Chapters 4 and 5 generate results that are dynamically embedded into this report. An update or alteration of this code followed by recompilation of this manuscript updates the tables and results accordingly.

Appendix B provides additional details and background information on various technical analysis indicators. Finally, Appendix C presents all the results generated in Chapters 4 and 5 collected together by the particular financial market.

## Chapter 2

# Literature Review

Speculators, stock market traders, market participants or simply traders are all terms used to describe individuals and organisations who attempt to make a living from buying and selling various financial assets in a huge range of markets around the world. Clearly the ability to forecast the direction of market movements, up or down, is vital to these individuals and entities. To this end a wide variety of techniques and methods have been tried and used by the participants in the market. Further, over the last few decades academics have shown an interest in this field and attempted to quantify and justify the wide variety of techniques used.

Two areas where traders and academics have looked for help in predicting future market direction is time series forecasting and the use of technical indicators. This chapter is divided into two these general categories, time series modelling and the use of technical indicators.

### 2.1 Technical Analysis

#### 2.1.1 Trading Systems

A wide variety of techniques have been employed by financial market traders in their attempts to make profits with the term “trading system” being applied generally to the methodology used. Often trading systems are “mechanical” in nature in that traders use a distinct set of rules in order to guide them as when to enter a trade, when to exit and so on. Faith (2007), one of the original and now famous “Turtle Traders” provides an excellent overview of mechanical trading systems (and how they were to become known as the “Turtles”).

Weissman (2005) makes the point that there are several aspects to a trading system. Firstly there are entry and exit signals, which are market events that trigger a speculator to enter into the market and either buy or sell a particular asset. These signals are typically events such as a fast moving average crossing a slower one, the market hitting a certain price or the occurrence of a particular chart pattern (see section 2.1.5). Other elements of a trading system include position sizing rules and money management strategies such that returns are significant, losses are minimised and the entire risk profile is controlled.

Many traders erroneously mistake entry and exit signals as being a full trading system in themselves whereas in actuality they are merely components of a system (Beau and Lucas, 1999). Likewise most, if not all, papers published by academia focus on entry and exit signals alone, which is probably a result of several factors. Firstly, entry and exit signals are important components in trading systems and are a good place to start in system development. Additionally, the other aspects of a system are not as well known and their importance is often ignored (Kaufman, 2013). Finally, testing an “entire” system as defined here is far more difficult and time consuming than considering entry and exit signals alone and often it is not practical to extend a study to include a full system. In summary there is value in considering entry and exit signal in isolation but one has to remember it is not the whole story.

Attempting to forecast stock market prices is a complex and challenging endeavour, yet one that is widely encountered. There is a large body of research published in this area which has been reviewed by Atsalakis and Valavanis (2009). Work usually focuses on either individual stocks or more commonly stock indices. Stock indices are the sum movements of many individual equities and therefore reflect the movement of the market as a whole as opposed to any one stock. Many stock market indices have been investigated including those belonging to well-developed countries such as those in Western Europe, North America etc. as well as developing markets such as those in Eastern Europe.

In trying to predict stock market movements a variety of input variables have been used. Frequently, the so-called OHLC (open, high, low and closing prices) are used as inputs along with a variety of technical indicators (Fiess and MacDonald, 2002). In addition, many authors have used a combination of markets, for example Huang et al. (2005) use both the USD/YEN exchange rate and the S&P 500 to build a prediction model for the Japanese NIKKEI index. A variety of predictive methodologies have been reported in the literature including linear and multi-linear regression, ARMA and ARIMA models, genetic algorithms (GA), artificial neural networks (ANN), random walk (RW) and the so-called buy and hold (B & H) strategy.

A variety of performance measures have been reported including both non-statistical and statistical methods. Non-statistical performance measures encountered include annual return and annual profit of a particular model as well as the hit rate or the number of times a model correctly predicts whether a market will go up or down. Alternatively a variety of statistical measures have also been employed and prominent amongst them are, mean absolute error (MAE), root mean squared (RMSE), mean squared prediction error (MSPE), correlation coefficient and autocorrelation squared correlation and Akaike's minimum final prediction error (FPE).

Two well studied and used methodologies in stock trading are the moving average system and range breakout system as reported by (Brock et al., 1992) in one of the very earliest papers published covering technical analysis. In a moving average system (see section 4.3.1) the speculator buys into a market when its price is above the moving average and sells in the reverse situation. A large number of variations on this theme can be found, with the use of two moving averages being popular. When using two averages there is normally a "fast" one, usually of the order of 10 to 25 days, and a "slow" one in the 50 to 250 day range. In these circumstances a buy is usually triggered when the fast average crosses above the slower average. The theory is that the moving averages follow the trends in the market and thus allow the market participant to trade in the direction of the trend, which is an advantageous situation for the trader.

A second popular idea is that of breaking out of a range. Often financial markets trade between a range of values in a particular time period, essentially markets are either trending (up or down) or not trending at all but moving within a defined range. While moving in a range the lower price boundary is referred to as support and the upper one as resistance. In a breakout system the analyst buys a market when it moves beyond these resistance levels or sells when it breaks below the support. Brock et al. (1992) analysed both these two ideas and found merit in them. Using daily data from the Dow Jones industrial index they found that these strategies provided better results than those generated with random walk, AR and GARCH models.

### **2.1.2 Technical Analysis Overview**

Technical analysis is the technique of looking at the past history of a financial market, identifying patterns and trends and utilising the information in predicting future price movements (Bulkowski, 2011). A technical indicator is a method used to identify a particular pattern, and there have been a large number developed over the years to predict situations such as the start of a trend or a reversal in price movement. A wide range of papers on technical analysis (TA) indicators and methods can be found in the

literature. Likewise technical analysis is prominent in many best selling books including *Market Wizards* (Schwager, 1988), *New Market Wizards* (Schwager, 1994) and *Covel's Trend Following* (Covel, 2009). In the following sections various technical indicators are introduced and their use in predicting market movements are explored. Firstly, the question of whether technical analysis even works is addressed, as this has received attention in the literature (Marshall and Cahan, 2005, Reitz, 2006, Schulmeister, 2009, Marshall et al., 2008). Although technical analysis is widely used in the market place there is a question mark over the entire concept behind it and many people, especially academics, are highly sceptical about the validity of the entire approach.

### **2.1.3 Does Technical Analysis Work?**

Friesen et al. (2009) have examined various price "patterns" used by traders in their systems such as "head-and-shoulders" and "double-top" patterns. The authors note that although a wide array of patterns have been identified and documented there lacks any convincing explanations for the formation of these patterns and how they can lead to profitable trading systems. The authors report that several studies based on the US equity market have identified distinct behaviours, namely the tendency for short-term momentum over 1 year to 6 months (De Bondt and Thaler, 1985, Chopra et al., 1992, Jegadeesh and Titman, 1993), longer term mean reversion and finally price reversals over the one to four week period (Jegadeesh, 1990, Lehmann, 1990, Jegadeesh and Titman, 1995, Gutierrez Jr and Kelley, 2008). These observations lend support to the success of trading systems that purport to detect and follow trends in the market (Sweeney, 1986, Levich and Thomas, 1993, Neely et al., 1997, Dueker and Neely, 2007).

The authors present a model that can explain the profitability of selected trading rules that utilise past chart patterns. One important aspect of this model is the inclusion of confirmation bias, which shows up in a wide range of decision making processes. Their model displays negative autocorrelations over the very short term, positive ones in the mid term and become negative again over the longer horizon, reflecting the documented empirical properties of US stock prices (Novy-Marx, 2012, Moskowitz et al., 2012, Fama and French, 2012). It is suggested that traders take market positions affected by their original biased view which leads to autocorrelations and price movement patterns resulting in the previously described market behaviour.

Shynkevich (2012) investigated the power of a large selection of technical trading rules to yield profits when applied a selection of small cap and technology portfolios (US stocks) between 1995 and 2010. The author chose technical indicators from four general categories:

1. standard filter rules - for example a buy is generated when prices increase from a previous low. Such a low may be defined as the lowest closing price in a particular period. In more recent years this technique has been replaced by moving averages.
2. moving averages (MA) - signals generated when short MA cross long MA.
3. support and resistance trading strategy (SR) - a buy is initiated when prices rise above a local maximum, and vice versa for a local minimum price.
4. channel breakout - related to SR, a buy/sell is triggered when a price moves outside a channel generated from highs and lows of a certain period.

The author applied a variety of parameters in each model resulting in a total of 12937 models being tested. It was reported that TA produced positive results in the first half of the time period tested, but not in the latter half. In the second half of the time period studied TA provided inferior performance than a buy-and-hold approach, i.e. a trader simply buys a particular asset and waits. The author concludes these differences in performance are due to equity markets having become more efficient in recent years which has reduced the short term predictive powers of TA.

The use of technical analysis in the finance community was studied by Menkhoff (2010) who looked into its use by professional fund managers. This study is noteworthy as it used data from experienced and educated market professionals and not a wider cross-section of traders. With the advent of the internet and the explosive growth in on-line financial charting and trading sites, financial trading became accessible to the general public, resulting in huge numbers of amateur traders entering the market. All of the web sites that cater for this segment of traders offer a huge number of technical analysis indicators built into their respective charting packages and even a rudimentary visit to any of the discussion forums will demonstrate the popularity and wide spread use of technical analysis.

The author surveyed 692 fund managers in several countries, with funds of various sizes under management. The vast majority of these fund managers reported using technical analysis to some degree and particular faith was put in TA for predicting price movements in the short term of up to a few weeks, beyond which focus shifts to fundamental analysis. Further, the workers found that smaller asset manager firms make greater use of TA, possibly because deriving the information for fundamental analysis is beyond their resources. Finally, most respondents to the survey believe that human psychology is the reason TA works. In particular they suggest psychological biases in the market participants are the root cause of market trends and that TA is able to identify and follow them.



### 2.1.4 Moving Average Indicators

A study of moving average convergence divergence (MACD) is reported by Ulku and Prodan (2013). MACD is a technique which attempts to detect the early stage of a trend as it forms, and is widely used by market participants. It is described in more detail in Appendix B section B.1. Ulku and Prodan (2013) apply MACD to a wide range of national stock market indices comprising developed as well as emerging markets. The authors compare the MACD signals against entry signals generated from simple break out systems (described previously). The comparison systems would generate a buy signal if the price moved higher than a moving average (MA), set at either 22, 56 and 200 days. The MACD and the comparison system using 22 day moving averages are classified as short horizon signals, while the break out of the 56 and 200 day MA are considered long horizon signals. The workers reported that the MACD indicators provide for profitable returns on 23 of 30 national indices, but that the 22 day MA performs better being positive in 27 of the 30 markets.

### 2.1.5 Candlesticks Patterns

Probably the oldest form of technical analysis in use today is the so-called candlestick analysis, so named because daily open and close prices are plotted such that they resemble candlesticks (Morris, 2006). Figure 2.1 is an example of daily prices being plotted as a candlestick, with this plotting methodology being ubiquitous today in trading software. Typically the colour in which the candlestick is plotted indicates whether the price went up or down over the course of the day. Many charts that are plotted in colour use green to represent days that close up and red for days that close down. The main body of the candlestick represents the movement from open to close, and the protruding lines mark the high and low of the day.

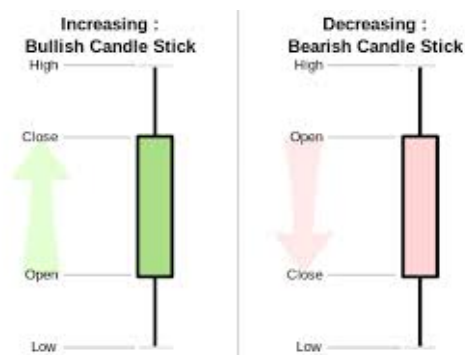


FIGURE 2.1: Candlestick representation of daily open and close prices. Different colouring is used to distinguish between prices going up or down.

Technical analysis via candlesticks is reputed to have been developed by Munelusa Homma, a legendary trader of rice in Osaka, Japan who made a fortune analysing rice prices with candlesticks in the seventeenth century (Nison, 2001). Candlestick patterns with supposed predictive qualities can be derived from a single day or from considering a few days, usually 2 or 3, together (Bigalow, 2011). There are a huge number of patterns recorded in the literature and usually assigned exotic names such as “White Marubozu”, ”Black Shooting Star” and ”Hanging Man”. Examples of such named patterns can be seen in Figure 2.2.

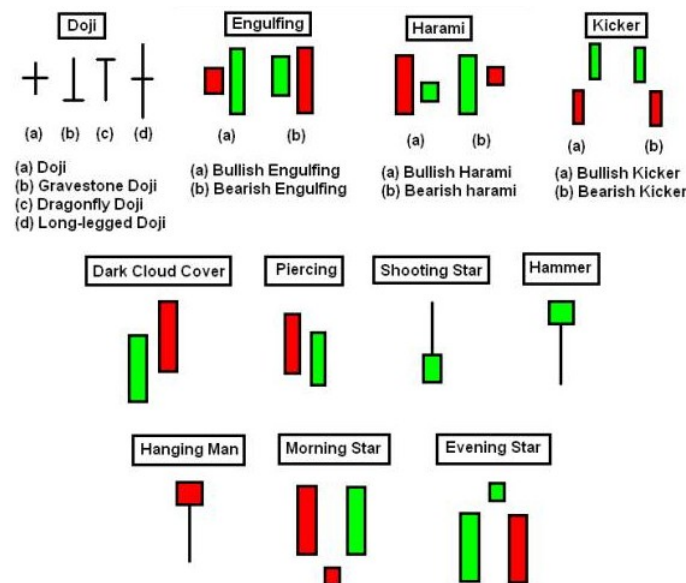


FIGURE 2.2: Examples of well known patterns encountered in candlestick analysis.

Candlestick patterns are essentially visualisation tools providing an easy to comprehend view of the market movements in a particular day. However there is some vital information which is not conveyed in a candlestick. In particular the order of events isn't displayed. Figure 2.3 shows how two days can produce the same candlestick but in actuality the price movements and volatility in them was very different. Depending upon the type of trading system being employed this could have important effects.

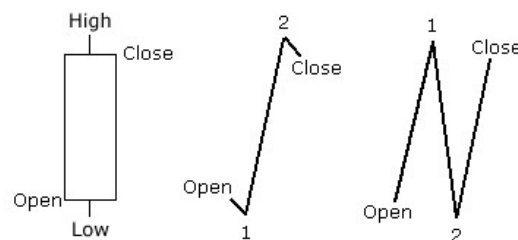


FIGURE 2.3: Candlesticks don't provide information regarding the order of price movements. Both these daily price movements would be represented with the same candlestick pattern.

As always with technical analysis there is doubt as to the validity of the methods despite its almost universal employment. An in-depth study of the predictive power of a range of candlestick patterns on stock prices between 1992 and 2002 from the Dow Jones Industrial Average (DJIA) was carried out by (Marshall et al., 2006) in which doubt was cast on the validity of candlestick patterns to predict market movements. The workers used a range of bullish (signals that indicate a trader should buy) and bearish (signals that indicate a trader should sell) candlestick patterns to initiate trades on the various stocks. Trades were held for ten days as it was assumed that these patterns reflect short terms trends and thus have a predictive power in a similar time frame. In order to quantify the results generated from the use candlestick patterns they were compared to results observed from four alternative null models. Simulated stock data was generated using a bootstrapping methodology (Efron, 1979) and then four null models were applied to the data, random walk, an autoregressive process of order one (AR(1)), a GARCH in-Mean (GARCH-M) model and an Exponential GARCH (EGARCH) model.

From the comparison of the results generated from the candlestick patterns and the four null models the workers concluded that the variety of candlestick patterns tested had no predictive power on the stocks at all. The returns from making buying and selling decisions based on candlestick patterns didn't outperform the null models on the simulated data. As always one has to be slightly careful with results of this nature as the trading period was fixed at ten days, in other words the candlestick patterns were used as an entry signal for the trade but there wasn't an exit signal. Further in reality use of candlesticks analysis would be incorporated into a trading system, which typically consists entry and exit signal, position sizing rules and money management strategies (Faith, 2007).

### **2.1.6 Trend Reversal Oscillators**

Tanaka-Yamawaki and Tokuoka (2007) reported the use of several technical analysis techniques in the successful prediction of price movements in eight stocks found on the New York Stock Exchange (NYSE) by analysing tick data. The predictions were in the very short term as tick data is the most granular level reported in financial data. The workers used ten technical analysis indicators from three broad classes, namely trend indicators, oscillators to find market reversals and momentum indicators to measure the strength of the market. Combinations of indicators, typically from the different categories are usually combined by market participants into a variety of systems. In this study the ten indicators can form a possible 1023 combinations. A genetic algorithm was used to determine the best combination of indicators for each stock, resulting in a customised combination for each. Using each stock's indicators, the next ten ticks of

data were modelled with very high accuracy, with predictions for IBM's stock being the best at a very impressive 82%.

## 2.2 Time Series Analysis

The study of forecasting time series data has been an active area of study for several decades and an overview of work over 25 years has been documented by De Gooijer and Hyndman (2006). Series data is ordered such that the ordering is an important if not critical aspect of the data and the requirement to maintain this ordering enforces certain constraints on its processing. Series data can be ordered by factors such as distance or height but typically time is the ordering encountered, and thus such collections are referred to as time series. Analysis of time series data is found in a wide range of areas including, Sales Forecasting, Speech Recognition, Economic Forecasting, Stock Market Analysis, Process and Quality Control and Seismic Recordings.

In general with non-series data we are interested in the relationships between the attributes of any particular row of data and perhaps how they affect the parameter we are interested in. Frequently some kind of regression technique is used in this kind of analysis in order to answer questions such as how is rainfall in an area affected by altitude or how does fuel consumption vary with car engine size (Han et al., 2011).

However with time series data there is an additional consideration, the relationship between the attribute's current value to that of its previous or later values. This is known as auto-correlation (Mills, 2011) and more details can be seen in section 2.2.2.1. Typically with financial data we are interested in previous values, in other words how is today's price of a security affected by the price one, two or three days ago?

As illustrated in Figure 2.4 a time series can contain some or all of the following components:

1. Trend - the overall direction of the series, is it increasing or decreasing over time?
2. Seasonality - regular variations in the time series that is caused by re-occurring events, for example a spike in sales during the Christmas period (So and Chung, 2014).
3. Random component - additional fluctuations in the series that may be attributed to noise or other random events.

There are three primary types of time series, stationary, additive and multiplicative. Stationary series have constant amplitude without a trend element and an example can

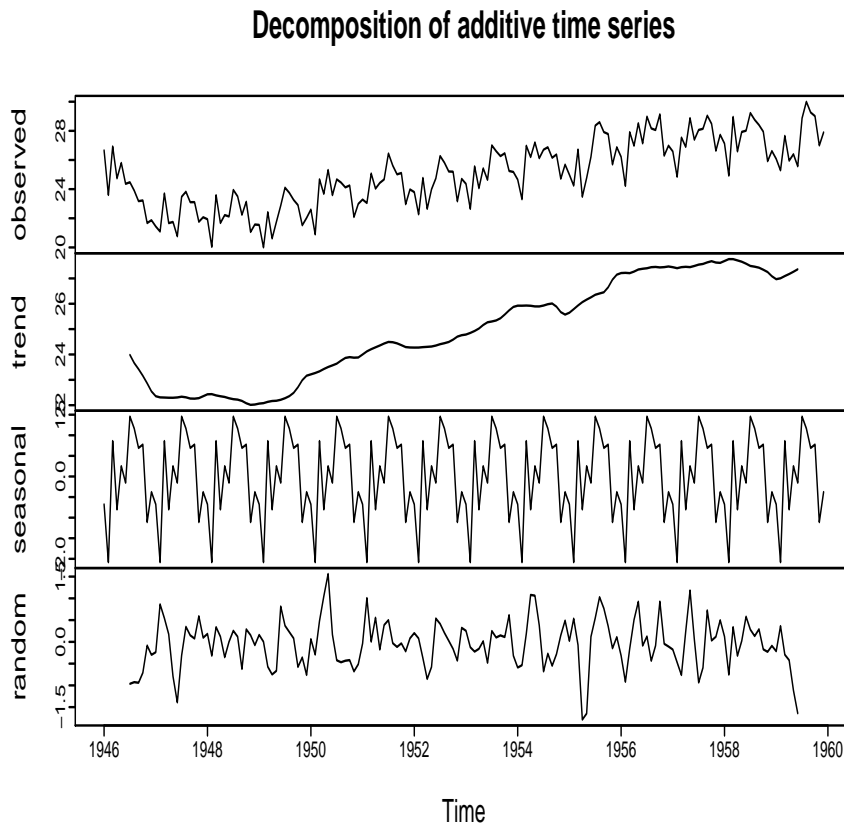


FIGURE 2.4: A time series decomposed into its three primary components.

be seen in Figure 2.5. Often stationary time series are repetitive, in other words showing constant auto-correlation and are considered the easiest type to model. A stationary time series can be composed of a seasonal element and/or a random component, thus:

$$\text{stationary time series} = \text{seasonality} +/\text{or noise}$$

The second type of time series is the additive type. In this type all three components of the series are present, trend, seasonality and noise. The distinguishing feature here is the amplitude of the seasonal component in that it is quite regular being static over time. An example of an additive series can be seen in Figure 2.6. This time series is trending upwards overall but there is a clear repetitive pattern of peaks and troughs caused by the seasonality, with the heights of the peaks all being similar. We can consider an additive time series as:

$$\text{additive time series} = \text{trend} + \text{seasonality} + \text{noise}$$



FIGURE 2.5: Example of a stationary time series which can be made up from noise and/or a seasonal component.

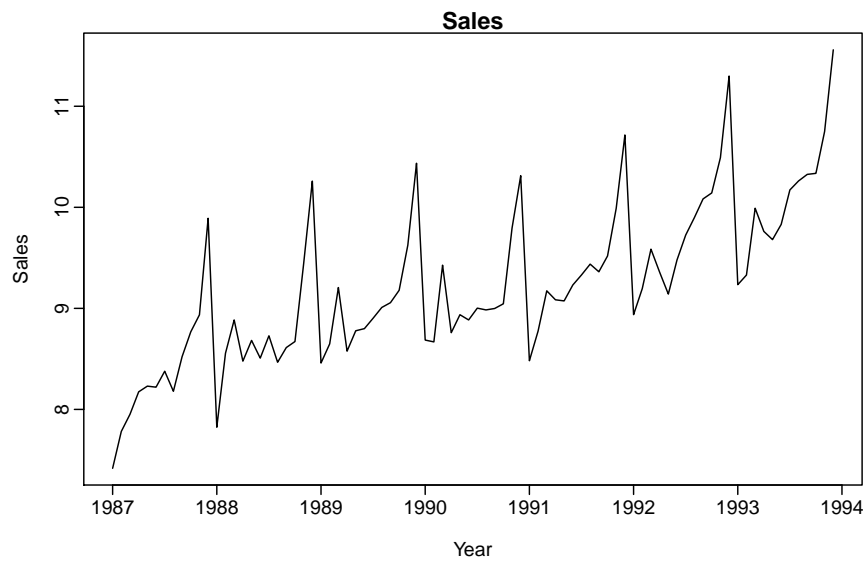


FIGURE 2.6: Example of an additive time series which results from all three components trend, noise and seasonality.

The third type of time series, as seen in Figure 2.7 is multiplicative. This is similar to the additive version except the amplitude of the seasonality increases over time. It can be considered as:

$$\text{multiplicative time series} = \text{trend} * \text{seasonality} * \text{noise}$$

Financial time series can be considered as containing all three elements of a time series. They can show properties of a stationary time series when they are range bound and only move between two values. At other times, markets trend strongly consistently, making

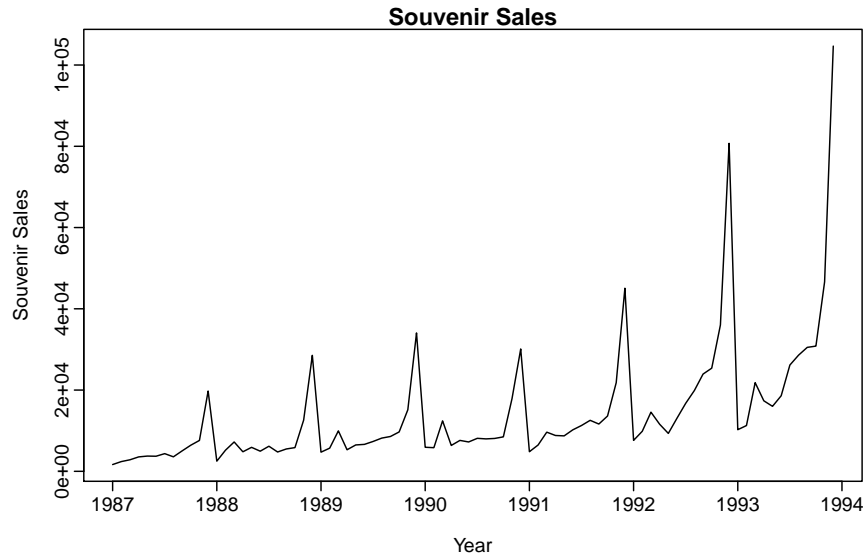


FIGURE 2.7: Example of a multiplicative time series resulting from the effects of trend, noise and seasonality.

new highs or lows and exhibit properties of an additive and occasionally a multiplicative series.

## 2.2.1 Time Series Smoothing

Smoothing is an important and widely adopted method to predict financial markets. Recent work on smoothing time series data has its origins in Brown (1959), Brown (1963), Holt (2004) and Winters (1960). Typically, the various smoothing techniques encountered are based around the concept of moving averages. This section will introduce a variety of smoothing methods commonly encountered in forecasting financial data.

### 2.2.1.1 Simple Moving Average (SMA)

A simple moving average is calculated from the value itself and its neighbours, which can be ahead or behind in the series. In this study values behind the current value are considered. The number of previous values included is often referred to as the “window” or “lag”, so if one was to consider the current value and four previous ones this would be considered a simple moving average of lag 5 (SMA5). An example of a simple moving average can be seen in Table 2.1, where a SMA5 of the closing price has been added.

TABLE 2.1: Example of a simple moving average of the closing price with a lag of 5 periods.

Date	Open	High	Low	Close	SMA5
02/01/14	9598	9621	9394	9400	NA
03/01/14	9410	9453	9368	9435	NA
06/01/14	9419	9469	9400	9428	NA
07/01/14	9446	9519	9417	9506	NA
08/01/14	9513	9516	9468	9498	9453
09/01/14	9492	9550	9403	9422	9458
10/01/14	9474	9530	9441	9473	9465
13/01/14	9498	9519	9457	9510	9482

### 2.2.1.2 Weighted Moving Average (WMA)

A simple moving average assigns equal importance to all data points being averaged, however if this is considered unsuitable a higher weighting can be applied to certain data points elevating their importance in the average and thus generating a weighted moving average (Devic, 2010). Typically the more recent data points in a time series would be given higher importance. One common version of a WMA is to decrease the weighting by one for each period in the average. The formula for calculating a weighted moving average is:

$$((n * P_n) + (n - 1 * P_{n-1}) + ... (n - (n - 1) * P_{n-(n-1)})) \div (n + (n - 1) + ... n - (n - 1))$$

where:

$n$  = the number of periods used in calculating the moving average

$P_n$  = the price of the most recent period used to calculate the moving average

An extra column has been added to the data in Table 2.1 which contains the WMA for the last five close values. The current value was multiplied by 5, the previous one by 4, the previous one to that by 3 and so on. These five values were added together and divided by 5+4+3+2+1 to generate the WMA as shown in Table 2.2.

### 2.2.1.3 Exponential Moving Average (EMA)

An exponential moving average (EMA) is an extension of the weighted moving average (Ord, 2004). In comparison to the simple moving average, greater emphasis is given to the most recent data points and the resulting averaged values are closer to the actual



TABLE 2.2: Example of a weighted moving average.

Date	Open	High	Low	Close	SMA5	WMA5
02/01/14	9598	9621	9394	9400	NA	NA
03/01/14	9410	9453	9368	9435	NA	NA
06/01/14	9419	9469	9400	9428	NA	NA
07/01/14	9446	9519	9417	9506	NA	NA
08/01/14	9513	9516	9468	9498	9453	9471
09/01/14	9492	9550	9403	9422	9458	9461
10/01/14	9474	9530	9441	9473	9465	9466
13/01/14	9498	9519	9457	9510	9482	9481

observations of the data set. Weighting factors decay exponentially resulting in the emphasis falling on the recent values though not discarding the older ones totally.

#### 2.2.1.4 Moving Averages in Practical Use

Moving averages are widely used in the financial world to predict the start of trends which is important as trends are considered the best opportunity to make profits from the markets. By their nature moving averages are lagged indicators in that they reflect market action from the past (recent or distant depending on the lag variable) and this can be considered a drawback. The lag period offers a trade off in terms of prediction. If the lag is short and/or weighting is applied the average is affected strongly by recent prices and trends can be detected in the early stages and trading profits can be enhanced. However when the average is close to the current price they have a tendency to generate “false signals” (see section 2.1.1 for an explanation of entry and exit signals), in other words prices may start to rise (or fall) but they are not actually in a trend, it is just the natural wax and wane of the market, and traders are said to be “whipsawed”. When the lag variable is long a different problem is encountered. For example, if a price moves above a long moving average the indicated trend is usually genuine, however by the time this is reflected in the average a lot of the trend has developed and the trader has lost a lot of potential profits. Thus there are pros and cons associated with using the different types of moving average.

#### 2.2.1.5 Holt-Winters Smoothing Models

The exponential smoothing of a time series containing noise, trend and seasonality was developed by Winters (1960) who as a student of Holt, built upon his previous work, and is today called the Holt-Winters method. This method uses three parameters alpha, beta and gamma which define the degree of smoothing to be applied to the three components

of the time series. Firstly, a value of alpha is used to dictate the amount of smoothing to apply, with high smoothing factors placing more emphasis on recent data points at the expense of those further away. In a data set with trend this simple exponential moving average doesn't perform well and a second order of smoothing is needed, so called "double exponential smoothing". The parameter beta in Holt-Winters defines this second order smoothing. Finally, if a seasonal component is also present in the data set a third level of smoothing is introduced making the process a triple exponential smoothing. It is this third level of smoothing that the parameter gamma refers to. Depending upon the nature of the time series one, two or all three of the parameters may be defined in the Holt-Winters methodology.

If researching a time series with no seasonality or trend use of the Holt-Winters model with the beta and gamma parameters set to false, in other words not used, is appropriate. Figure 2.8 shows the addition of an exponential smoothing line to the stationary data set introduced in Figure 2.5.

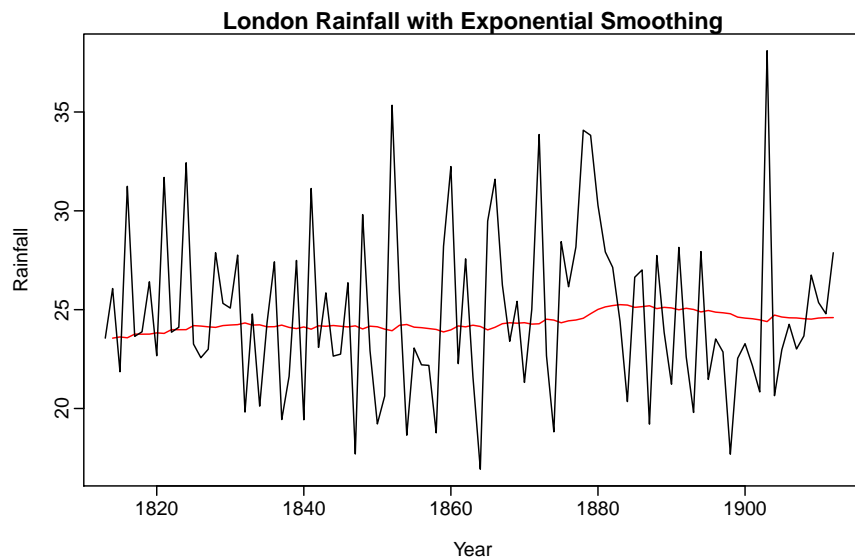


FIGURE 2.8: A time series with no seasonality or trend, showing the fitted line generated from Holt-Winters exponential smoothing with the beta and gamma parameters set to false.

If the time series is additive with a trend but without seasonality the use of Holt-Winters with values used for alpha and beta but with the gamma parameter set to false is appropriate. Such a time series can be seen in Figure 2.9 with the exponential smoothing. Finally if the time series contains all three components a smoothing line can be fitted using Holt-Winters exponential smoothing in which there are values for all three terms alpha, beta and gamma. Figure 2.10 is an example of a time series with both trend and seasonality and overlaid with Holt-Winters smoothing generated by using values for all three terms in the smoothing algorithm.



FIGURE 2.9: A time series with trend though no seasonality, showing the fitted Holt-Winters exponential smoothing with the gamma parameter set to false.



FIGURE 2.10: A time series with trend and seasonality, showing the fitted Holt-Winters exponential smoothing.

## 2.2.2 Auto-Regression Family of Models

### 2.2.2.1 Auto-Regression

Regression is the study of the impact of known variables (independent) on an unknown (dependent) variable and addresses questions such as how does a person's income vary with their years of education. The general equation for linear regression is given by:

$$y = a + bx + \varepsilon$$

where:

$a$  is the intercept.

$b$  is the co-efficient.

$x$  is the independent variable.

$\varepsilon$  is the error term.

In reality there are often a large number of independent variables that affect the unknown under study and thus multiple regression, shown below, is usually of interest.

$$y_1 = a + b_1x_{1i} + b_2x_{2i} + \dots + b_nx_{ni} + \varepsilon$$

In a time series the preceding values often have a bearing on the current data point, and this is especially important in financial time series data. Thus auto-regression is the prediction of the current point from the use of previous values of the data point itself, and is given by:

$$t_t = c + b_1 * r_{t-1} + b_2 * r_{t-2} \dots b_p * r_{t-p} + \varepsilon$$

where:

$c$  is the intercept, is often zero and the mean of the time series.

$b_1 - b_p$  are the independent variables, the previous values.

$\varepsilon$  is random noise.

### 2.2.3 Auto-Regressive Moving Average (ARMA)

The auto-regressive moving average (ARMA) model, also known as Box-Jenkins (Box and Jenkins, 1970), combines moving averages with auto-regression. A model that uses moving averages to predict current values is given by:

$$-r_t = c + a_1 * ma_{t-1} + a_2 * ma_{t-2} \dots a_q * ma_{t-q} + err_t$$

ARMA combines the moving average model with auto-regressive terms to generate:

$$\begin{aligned} r(t) = & c + \\ & b_1 * r_{t-1} + b_2 * r_{t-2} \dots b_p * r_{t-p} + \\ & a_1 * ma_{t-1} + a_2 * ma_{t-2} \dots a_q * ma_{t-q} \\ & + err \end{aligned}$$

where:

$c$  is the intercept, which is often zero and the mean of the time series.

$b_1 - b_p$  are the independent variables, the previous values in the auto-regression term.

$a_1 - a_p$  are parameters of the moving average model.

$\varepsilon$  is random noise.

An ARMA(1,1) model uses the previous value in the auto-regression term and the previous value's moving average. Thus in general terms an ARMA(p,q) model uses the previous p values in the auto-regression term and the moving averages derived from the last q values. There are therefore three steps in developing an ARMA model:

1. identification step in which the order of AR and MA components is determined
2. parameter estimation
3. forecasting

ARMA models have certain intrinsic properties that may be considered drawbacks, namely the requirement for the time series to be stationary with no trend and also linear and the difficulty in deriving the correct parameters to use in the model. In order to overcome these restrictions researchers have tried a number of approaches to enhance the effectiveness of ARMA models.

The problem of model and parameter selection in ARMA models has also been addressed by Rojas et al. (2008). The authors make the point that in traditional research choosing the correct model is time consuming and requires a large degree of expertise. In order to circumvent these issues they propose an automatic model selection method to speed up the process, remove the need for expert intervention and allow the processing of a large number of time series. In a similar study Qian and Zhao (2007) investigate how to determine model selection where there are potentially millions of candidate ARMA models available for the time series. Again, the authors propose an automatic selection algorithm centred on the Gibbs sampler. The proposed method allows for various problems typically encountered in selecting ARMA models and the resulting choice was used to generate a prediction of China's Consumer Price Index (CPI).

#### **2.2.4 Auto-Regressive Integrated Moving Average (ARIMA)**

One limitation with the ARMA model and indeed other approaches is that it is assumed that the time series is stationary, it doesn't have trend and has constant variance and mean (Shumway and Stoffer, 2010). In reality of course many time series data sets have

trend, and in the world of financial data this is also true. In order to account for trend in a time series it is often transformed into a stationary data set, modelling is then performed on this adapted data after which it is returned to its original state. In effect the trend aspect is removed, modelling is done, then the trend component is added back into the data.

One such method for removing trend is differencing (Mills, 2011). Differencing is the technique of replacing the actual values of the observations with the values of the differences between them. This is represented as:

$$Diff1_t = r_t - r_{t-1}$$

Differencing is the same as calculating the derivative of the series, thus a time series that has undergone differencing is considered “integrated”. If taking this so-called first difference doesn’t remove the trend one can go further and use the second difference:

$$Diff2_t = (r_t - r_{t-1}) - (r_{t-1} - r_{t-2})$$

Addition of an integration step to the ARMA model results in an auto-regressive integrated moving average (ARIMA) model, with the general formula:

$$\begin{aligned} r(t) = & c + \\ & b_1 * r_{t-1} + b_2 * r_{t-2} \dots b_p * r_{t-p} + \\ & a_1 * ma_{t-1} + a_2 * ma_{t-2} \dots a_q * ma_{t-q} \\ & d_1 * diff_{t-1} + d_2 * diff_{t-2} \dots d_d * diff_{t-d} \\ & + err \end{aligned}$$

where:

$c$  is the intercept, which is often zero and the mean of the time series.

$b_1 - b_p$  are the independent variables, the previous values in the auto-regression term.

$a_1 - a_p$  are parameters of the moving average model.

$d_1 - d_p$  are the parameters of the differencing term.  $\varepsilon$  is random noise.

ARIMA models are usually referenced as ARIMA(p,d,q) with p the number of terms used in the auto-regression, d the number of differencing terms and q the number of

terms used in the moving average. A summary of which model (Holt-Winters, ARMA or ARIMA) to use with which type of time series can be seen in Table 2.3.

TABLE 2.3: Appropriate models for use with time series data.

Model	Time Series Required	Assumes Correlation	Trend	Seasonality
Holt-Winters	Short Term	N	Y	Y
ARMA	Stationary	Y	N	Y
ARIMA	Non-stationary: Additive or Multiplicative	Y	Y	Y

### 2.2.5 ARIMA Parameter Selection

An important aspect of building time series models with ARIMA techniques is the choice of parameters to use. Auto-correlation (AC) and partial auto-correlation (PAC) are important measures in the selection process of these parameters (Mills, 2011).

Correlation is the measure of how one variable changes with a second one. For example if variable A increases while variable B increases they are positively correlated and conversely they are negatively correlated when one decreases as the other increases. Further, correlations are measured by degree on a scale of 1 to -1, with 1 being perfectly correlated. A value of 1 indicates that the two variables increase together perfectly in sync, whereas a value of -1 suggests that as one variable increases the other decreases by the same amount. Finally a value of 0 is indicative of no correlation at all between the two variables.

Auto-correlation is the correlation between an attributes value now and the same attribute's value in the past or future (Shumway and Stoffer, 2010). Typically with financial data we are interested in the correlation with values in the past. The interval between the value of interest and the previous observation used in determining the correlation is known as the lag. Thus the correlation between the current observation and the previous one may be of interest, and this is a lag of +1, while a value five time intervals previous is +5. Non-intuitively positive values for lags refer to the past while negative values are in the future.

A correlogram is a matrix plot of auto-correlations over a series of time lags. Correlograms are used in checking data for randomness and in the model identification stage of the ARMA methodology (see section 2.2.3). Data is considered random if the auto-correlation value is close to zero. In general a data set's randomness needs to be checked

in order to confirm the validity of many statistical tests. Thus a correlogram helps to determine if data is random or if an observation is related to an earlier one, thereby helping in the determination of an appropriate ARMA model. Figure 2.11 is the correlogram of auto-correlation and Figure 2.12 the correlogram of partial auto-correlation for a data set of rain fall figures.

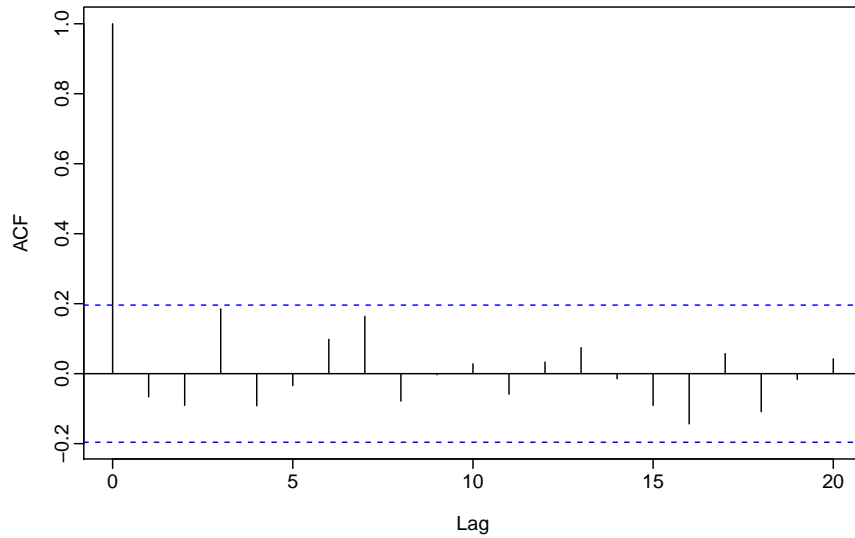


FIGURE 2.11: Correlogram of auto-correlations.

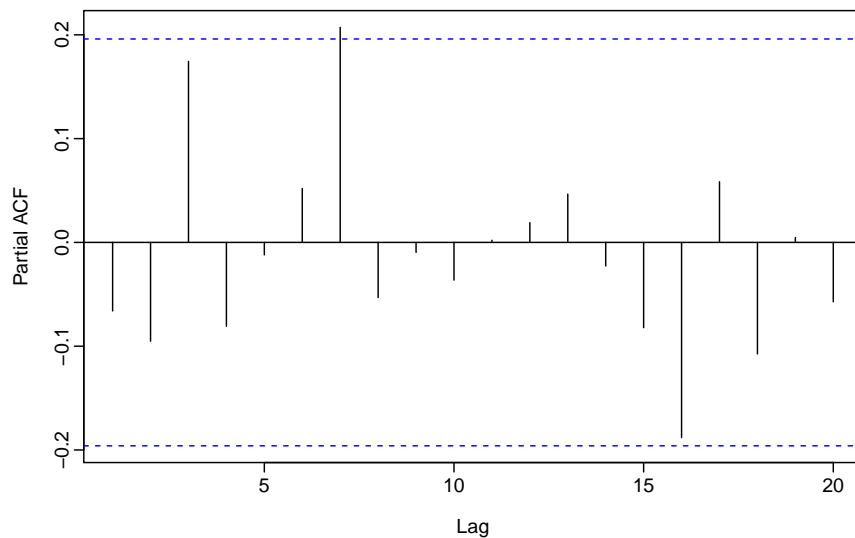


FIGURE 2.12: Correlogram of partial auto-correlations.

The partial correlation is defined as the degree of correlation not already explained by the correlations previously measured. If the regression of variable A on variables B1, B2 and B3 is considered the partial correlation between variables A and B3 is the degree of correlation not accounted for by their common correlations with variables B1 and B2. In a similar manner the partial autocorrelation is the unexplained correlation after considering the variable and itself at an earlier time period. In a series, if a variable



A at time  $t$  is correlated with an earlier lag at time  $t-1$  it follows that the variable at  $t-1$  itself is correlated with the previous variable at lag  $t-2$ . By extension the variable at time  $t$  should also be correlated with the variable at lag  $t-2$ , as the correlation will propagate through the series. The partial autocorrelation is the difference the expected correlations due the propagating factors and the actual correlation measured.

If the ARIMA model is  $ARIMA(p,d,0)$  or  $ARIMA(0,d,q)$  then the ACF and PACF plots are helpful in deciding the values for  $p$  or  $q$ . If both  $p$  and  $q$  are positive, the ACF and PACF are not useful in estimating the values for  $p$  and  $q$ . An  $ARIMA(p,d,0)$  model may be appropriate if the ACF and PACF plots of the stationary data exhibit an exponentially decaying pattern in the ACF and a large spike at lag  $p$  in PACF plot. Conversely an  $ARIMA(0,d,q)$  model may be appropriate if the PACF is decaying exponentially and there is there is a significant spike in the ACF plot at lag  $q$ .

### 2.2.6 Hybrid Models

Auto-regressive (integrated) moving average models have shown themselves to be important modelling methods for time series data, including financial time series data. However the techniques have limitations that have detracted from their popularity, namely their assumption of a linear relationship and the need for a lot of data to produce accurate results. In order to address these limitations a variety of hybrid solutions have been proposed in which ARIMA models are combined with other techniques, often non-linear prediction algorithms (Wang et al., 2012, Khashei and Bijari, 2012, Aladag et al., 2009).

One combination that has found a lot of attention in the literature is the combination of Artificial Neural Networks (ANNs) with ARIMA. Khashei et al. (2009) report on the use of this combination in a attempt to predict the future price movement in gold and US dollar / Iran rials financial markets. The workers report favourable results in comparison to the techniques alone and suggest the method as having potential for accurate predictions of non-linear time series data. In a similar study Zhang (2003) applied a combination of ARIMA and ANN to various data sets including the British pound / US dollar exchange rate. They observe that in the literature in general these two popular techniques are frequently compared in terms of predictive power with the reported results non-conclusive. Results from the three data sets modelled show that the combination of the two methods outperform the individual ones when the mean squared error (MSE) and mean absolute deviation (MAD) are used as the measure of forecasting accuracy.

Fatima and Hussain (2008) also investigated the impact of a hybrid approach in modelling short term predictions for the Karachi Stock Exchange index (KSE100). The

authors reported comparison results for ANN versus ARIMA and a hybrid of ANN/ARIMA. The hybrid solution out-performed the individual ARIMA and ANN models. It is postulated that a rationale for this is that at any point in time financial markets are subject to linear, non-linear and volatility patterns as the cumulative effects of government fiscal and monetary policies and general rumour and political instabilities feed into the market. Under these complex conditions simple models can only capture one aspect of the underlying factors affecting the price series. A hybrid combination approach is more successful as more of the market variance is modelled.

Kriechbaumer et al. (2014) reports on a further hybrid approach to forecast the prices of aluminium, copper, lead and zinc. Previous research has indicated that these markets exhibit a strong cyclic behaviour. In an attempt to factor this into the predictive model ARIMA was coupled with a wavelet approach. Wavelet analysis decomposes a time series into its frequency and time domains in an attempt to isolate this cyclic behaviour. The performance of the ARIMA modelling was shown to be enhanced substantially by the addition of wavelet based multi-resolution analysis (MRA) before performing the ARIMA analysis.

Tan et al. (2010) have also reported the combination of wavelet analysis and ARIMA in the prediction of electricity prices. The general method employed is to transform the original time series data set into a collection of sub-series through the application of wavelet analysis. Subsequent to the transformation a prediction for each sub-series can be made with ARIMA modelling. The final forecasted result is obtained by reforming the sub-series back into the original time series. The authors report results showing the enhanced predictive power of the ARIMA wavelet hybrid approach compared to ARIMA and GARCH models used in isolation.

Pai and Lin (2005) reported on attempts to overcome the limitation of ARIMA models in that the time series must be linear by use of an hybrid ARIMA / Support vector machine (SVM) combination. SVM have been successfully applied to non-linear regression problems and the authors have harnessed the strengths of both methodologies in order to predict the prices of a selection of fifty stocks. Results from the work show that the hybrid method out-performs the ARIMA and SVM methods individually.

Rout et al. (2014) report the use of ARMA models in the prediction of exchange rates. The workers note the limitations of ARMA in that the time series data must be linear and stationary, a condition often not met in practical situations and the difficulty in deriving steps one and two (listed previously) in developing the ARMA model. In order to overcome these limitations ARMA is combined with differential evolution (DE) in order to determine the models feed-forward and feed-back parameters. The results from the

prediction models generated are compared with models resulting from ARMA in conjunction with particle swarm optimisation (PSO), cat swarm optimisation (CSO), bacterial foraging optimization (BFO) and forward backward least mean square (FBLMS). The workers conclude that the ARMA - DE model produces the best short and long-range predictions from the options tested and is a potentially valuable method in predicting exchange rates on the international finance markets.

## Chapter 3

# Methodology

### 3.1 Data Collection and Quality

The data used in this study was freely collected from the Yahoo finance web site ([www.yahoo.com](http://www.yahoo.com)). It is of high quality with no missing values and represents the opening, high, low and closing prices for each day that the particular market indice was open for trading.

### 3.2 Data Description

Data from a variety of national stock market indices was employed in this study. The indices were from a variety of geographic locations with FTSE (UK), DAX (Germany) and CAC (France) all being in Europe, the Dow is from the US, the Nikkei from Japan and AORD from Australia. The data is in the form of so-called daily OHLC (daily open, high, low and close prices) for Monday to Friday (excluding appropriate national holidays) for the period 2000 until the end of 2013. A schematic representation of daily OHLC data can be seen in Figure 3.1. The first six observations from the DAX data set (German national indice) can be seen in Table 3.1.

The final six observations from the DAX data set can be seen in Table 3.2. Over the period of the data (2000 until the end of 2013) the DAX started at 6691 and finished at 9552. Summary statistics for the DAX data set can be seen in Table 3.3. The data set contains 3621 observations and the closing price has ranged between 2202 and 9742 over the period. A graph of the closing prices from 2000 to 2013 can be seen in Figure 3.2 and a graph for 2013 can be seen in Figure 3.3.

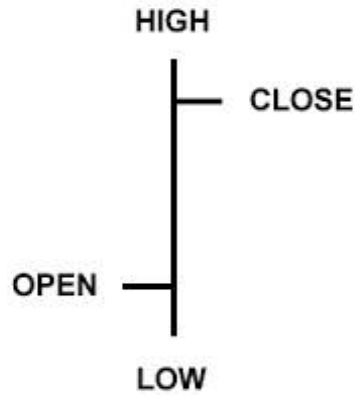


FIGURE 3.1: A schematic representation of open, high, low and closing prices (OHLC).

TABLE 3.1: First 6 rows of the DAX data set

Date	Open	High	Low	Close
03/01/2000	6962	7159	6721	6751
04/01/2000	6747	6755	6510	6587
05/01/2000	6586	6586	6389	6502
06/01/2000	6501	6539	6403	6475
07/01/2000	6490	6792	6470	6781
10/01/2000	6785	6975	6785	6926

TABLE 3.2: Final 6 rows of the DAX data set

Date	Open	High	Low	Close
16/12/2013	9005	9188	8998	9164
17/12/2013	9143	9162	9085	9085
18/12/2013	9145	9191	9122	9182
19/12/2013	9280	9352	9257	9336
20/12/2013	9371	9413	9353	9400
23/12/2013	9400	9400	9400	9400

TABLE 3.3: Summary statistics of the DAX data set.

Statistic	N	Mean	St. Dev	Min	Max
Open	3,621	5,858.36	1,559.40	2,203.97	9,752.11
High	3,621	5,906.70	1,561.17	2,319.65	9,794.05
Low	3,621	5,804.85	1,557.49	2,188.75	9,714.02
Close	3,621	5,857.74	1,559.39	2,202.96	9,742.96

Each data set has a particular set of characteristics and these are important when technical analysis and other analytical techniques are applied to the data set (Chen and Li, 2014, Matheson, 2012). A variety of these are explored in the following sections. The average amount a market moves is investigated and the term Average True Range



FIGURE 3.2: Graph of German DAX between 2000 and 2013.

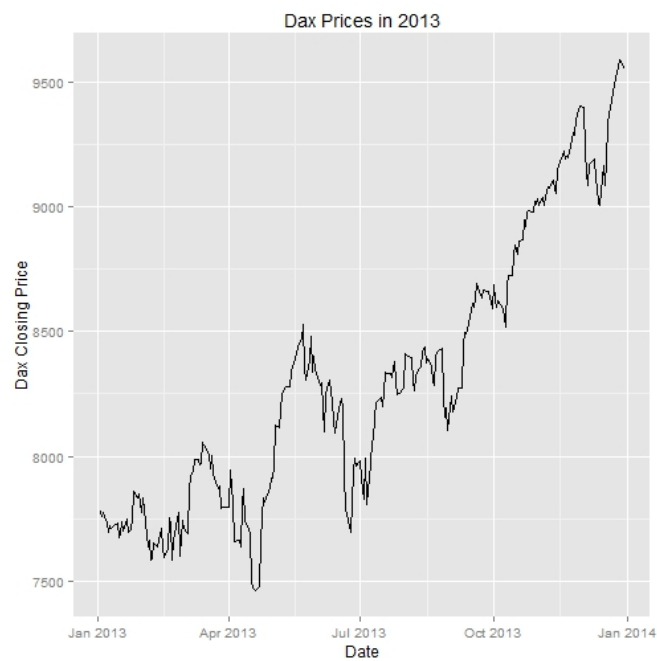


FIGURE 3.3: Graph of German DAX in 2013.

is introduced and defined for the data sets. Where the opening and closing prices are in relation to the previous day's high and low values are also considered. Finally, the distance between the day's opening and high prices and opening to low prices are investigated. The relative ratios of these values are important when considering which technical analysis may be best suited to a particular market.

### 3.2.1 Average True Range (ATR)

Wilder (1978) introduced the concept of Average True Range (ATR) as a way to measure a market's volatility or the amount the price is likely to move in any one day. Initially the True Range (TR) is calculated as the maximum of:

1. the today's high price minus today's low price.
2. the absolute value of the today's high minus the previous day's closing price.
3. the absolute value of the today's low minus the previous day's closing price.

Having calculated the TR, an average of a previous number of days is used to derive the ATR. Typically the TR values from the previous 14 days are used.

Absolute values are used in the calculation of the ATR as we are not concerned with the market direction but rather the the amount the market is likely to move. ATRs are typically quoted as absolute values and as such markets trading at higher prices will have higher ATRs. For example the Japanese Nikkei with a value of 14000 will move more in a day than the French CAC with a value in the 4000's.

Dividing the ATR by the closing price is a useful way to see how a security's volatility varies over time. Table 3.4 shows summary statistics for the ATR and ATR divided by closing price and Figure 3.4 is a graph of how ATR divided by closing price has varied for the DAX between 2000 and 2013. In absolute terms the ATR varied between 36 and 316, however the value of the indice itself varied a lot. Looking at the ATR value divided by the closing period it can be seen that over the period of 2000 to 2014 the mean value is approximately 2. Thus on average the market can be expected to move 2% of the closing price in any one day. However this value has varied between 0.7% in periods of low volatility to a value of 6.7%.

### 3.2.2 Opening Price

Where a market opens in relation to the previous day's high and low price varies across the data sets. This is important and can influence the technical analysis indicator or

TABLE 3.4: ATR and ATR divided by closing price for the DAX between 2000 and 2013

Statistic	N	Mean	St. Dev	Min	Max
ATR	3,556	108.29	45.53	36.07	316.04
ATR/Close	3,556	1.995	1.065	0.700	6.740

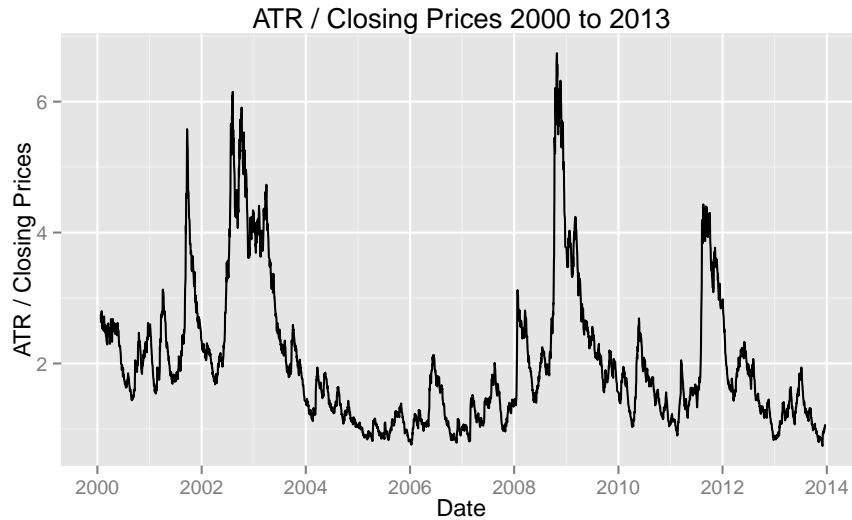


FIGURE 3.4: ATR of DAX divided by closing price between 2000 and 2013.

trading system to utilise. Table 3.5 lists opening price statistics for a variety of national indices. The table lists the number of times that opening prices are between the previous day's high and low prices. These statistics are useful in characterising a market in terms how they move out of hours and can have an impact when choosing a trading system.

TABLE 3.5: Opening prices in relation to the previous day's high and low values.

Market	Opening Price between Previous Day's High and Low (%)
DAX	75
FTSE	90
CAC	60
Dow	98
Nikkei	53
AORD	79

### 3.2.3 Closing Price

In a similar fashion to the opening prices the position of the closing prices in relation to the previous day's high and low price are also of interest. In this case, the percentage of closes outside the previous high / low price may indicate that the market may be a good



choice for a breakout type of trading system (see section 4.6.1 for details of breakout systems). Likewise the opposite situation occurs if a market frequently finishes within the previous day's high and low levels and may be a candidate for a reversal type of system. The statistics for various national indices can be seen in Table 3.6. Looking at these figures it would suggest that the Dow with a low ratio of finishing outside the previous period's high low values may be a candidate for a reversal type of system and conversely the Japanese Nikkei has a high percentage value and potentially a candidate for a break-out system.

TABLE 3.6: Number of occasions when closing prices finished outside the previous day's high or low values.

Market	Closing Price outside Previous Day's High and Low (%)
DAX	56
FTSE	56
CAC	58
Dow	39
Nikkei	63
AORD	60

The range from opening price to closing price, either up or down, is of interest. Table 3.7 lists the minimum and maximum values in this range and Table 3.8 shows the quantiles for this price range.

TABLE 3.7: Minimum and maximum values for the open to close price range.

Market	Min Value	Max Value
DAX	0	508
FTSE	0	431
CAC	0	313
Dow	0	950
Nikkei	0	1333
AORD	0	347

TABLE 3.8: Quantile values for the open to close price range.

Market	25%	50%	75%	90%
DAX	16	39	75	508
FTSE	15	33	63	431
CAC	11	26	49	313
Dow	27	61	119	950
Nikkei	32	71	133	1333
AORD	8	19	36	347

### 3.2.4 High / Low Price

Table 3.9 shows the percentage of times that either today's high price crosses yesterday's high or today's low prices dips below yesterday's low value. The final closing price may be between yesterday's high and low or outside of it. The second column of Table 3.9 is the number of times when today's values crossed both the previous low and the previous high in the same day. This is also known as an Engulfing Candlestick (see section 4.7.2). In all the indices the previous day's high or low value is reached the following day in a large number of instances, in the case of the Nikkei 90% of the time. Conversely, the likelihood of both the previous day's high and low values being touched are low, only 5% of occasions in the Australian AORD.

TABLE 3.9: Number of occasions when today's high or low prices crossed the previous day's high or low values.

Market	Crosses either previous day's High or Low (%)	Crosses both the previous day's High and Low (%)
DAX	89	9
FTSE	87	8
CAC	90	10
Dow	88	9
Nikkei	90	8
AORD	86	5

### 3.2.5 OH/OL Price Fluctuations

The movements in prices between the open and high (OH) and open to low (OL) are interesting and can have an influence on any trading systems developed. On any given day prices open, move to their lowest point, move to their highest point and then close (not in any particular order). From the OHLC data used in this study the order of these events can not be determined or even the number of times in a day these price points are reached.

In this section we are concerned with the relative sizes of these two price movements, the day's high price minus the opening price (OH) and the opening price minus the low price (OL), one of which is usually greater than the other. We will define the daily "minor" price fluctuation as the smaller of the two price movements. Likewise we will define the larger value as the "major" price fluctuation.

Considering the minor price fluctuation, the range of values encountered in the indice markets under study can be seen in Table 3.10. In all cases the minimum value is zero, in other words the market opening price and either the day's high or low price were

the same, the market didn't dip below or above this level. The second column in Table 3.10 is the maximum value. In the case of the German DAX, there was a day when the market moved 189 points away from its opening price but also moved further in the opposite direction away from the opening price. Clearly this was a highly volatile day on the German markets.

TABLE 3.10: Minimum and maximum values for the smaller of the daily OH or OL price movement - the "minor" move.

Market	Min Value	Max Value
DAX	0	189
FTSE	0	186
CAC	0	134
Dow	0	379
Nikkei	0	310
AORD	0	114

The quantiles of the minor price movements can be seen in Table 3.11. The 90% quantile is the level at which 90% of the time the minor move is less than this level. This value may be important to know and understand when considering break-out type of systems (see section 4.6). Looking at the value of the DAX we can see that the 90% quantile level occurs at 46, which indicates that if the market has moved to this level it is unlikely to be the day's minor move (whose level 90% of the time is below this). Perhaps a break-out type of system may be profitable at this point, as once the market has moved this far it is usually a major move and may be expected to continue further in the same direction.

TABLE 3.11: Quantile values for the smaller of the days OH or OL price movement - the "minor" move.

Market	25%	50%	75%	90%
DAX	5	15	29	46
FTSE	0	7	20	33
CAC	4	11	19	31
Dow	12	43	75	113
Nikkei	5	21	43	72
AORD	0	1	7	13

In contrast to the minor daily price fluctuation, the "major" price fluctuation is defined as the largest of the OH or OL values. The range of values encountered in this price fluctuation in the indice markets can be seen in Table 3.12 and the quantiles of the major price movements can be seen in Table 3.13. Considering the DAX once more, it can be seen that the 25% quantile is approximately equal to the 90% quantile of the minor fluctuation. Thus if the DAX moves approximately 50 points away from the opening it is unlikely to be the smaller of the price movements and much more likely to be part

of the larger movement. Knowledge of the minor and major price fluctuations may be useful in developing trading systems.

TABLE 3.12: Minimum and maximum values for the larger of the days OH or OL price movement - the “major” daily price fluctuation.

Market	Min Value	Max Value
DAX	0	530
FTSE	0	471
CAC	0	359
Dow	0	992
Nikkei	0	1737
AORD	0	347

TABLE 3.13: Quantile levels for the larger of the day’s OH or OL price movement - the “major” daily price fluctuation.

Market	25%	50%	75%
DAX	43	69	106
FTSE	37	56	86
CAC	30	45	69
Dow	92	131	190
Nikkei	76	118	184
AORD	18	30	48

A final consideration in this section is the range of the open to close prices detailed in section 3.2.3. Again considering the German DAX it can be seen that the 50% quantile value is 39, as shown in Table 3.8, which is below the 90% minor fluctuation level.

## 3.3 Software Tools

### 3.3.1 R and R Studio

Experimental results and graphs were produced with the open source programming language R version 3.0.2. For help in the creation and organisation of the R code for this thesis the open-source development environment R Studio version 0.98.490 was used extensively. The following packages were immensely helpful in the preparation of this thesis:

- TTR - provided technical analysis functions
- xts - irregularly spaced time series
- forecast - time series forecasting

- candlestick - Japanese candlestick patterns

### 3.3.2 Rapid Miner

Rapid Miner version 5.3, a market leading open-source data mining and predictive analytic platform, was used for building hybrid ARIMA models. The base system and time series plug-ins were used.

## 3.4 Methodology

The aim of this study was to predict market movement, not in terms of absolute values but more in terms of general direction. The trading algorithms developed in this study were based around a daily time period. The data used was daily data containing open, high, low and closing prices. The trading algorithms developed typically opened a trade at the day's opening price and closed them at the day's closing prices. There are some deviations from this, for example trades are closed at some pre-defined point in the event of a stop loss being entered or trades running from close to close, and these are detailed in the text at the appropriate place. The forecasts produced from the technical analysis and time series models were consumed by the trading algorithms and used to decide in which direction the daily trade would be made, i.e. would the market rise or fall.

The success or failure of any particular method was determined by the number of points gained or lost in these trading algorithms. In turn these points can be considered money and the net number of points can represent a profit or loss (PL). The results presented in Chapters 4 and 5 report either the total PL of a system or the average PL per trade. The latter value is probably most useful when it comes to comparing systems that don't enter trades every day, for example when one uses candlestick patterns which only occur very infrequently. Also the direction of trade is also a consideration. Results are separated into long (a buy is made in the expectation of the market rising) or short (a sell is made in the expectation of the market falling).

## Chapter 4

# Technical Analysis

### 4.1 Introduction

This chapter investigates whether technical analysis can provide a positive expectancy for financial traders (Kuang et al., 2014, Hsu et al., 2010). A variety of technical analysis indicators are employed including MACD, Aroon, Stochastics Oscillator and Rate of Change (ROC) indicator. The experimental results from using these indicators are presented in groupings based on the general category of indicator such as trend identification, market reversal and momentum indicators (Taylor, 2014). Some technical indicators have a role to play in more than one area, for example MACD can be considered a trend detection indicator or a market reversal indicator.

The effectiveness of a particular indicator or system is measured in terms of “points” gained, which is also referred to as “PL” (which stands for profit and loss). The results presented in this chapter are mainly based around systems in which a trade is opened and closed each day, producing a daily PL either positive or negative. The sum of all the individual days produces the total system PL and these values are reported in the results tables. For example, if the market moved from 6000 to 6200 in any one day a PL of either 200 ( $6200 - 6000$ ) or -200 ( $6000 - 6200$ ) depending upon which way the trade was placed, would be added to the overall system results.

In addition, the results are presented such that returns from “going long” (expecting the market to rise) are presented separately from the opposite scenario of “going short”. This is because market behaviour is often different while it is rising than it is while falling and systems may be more adept at predicting price movements in one of the directions. Further, transactions costs are not taken into account in the results and these would typically be 1 point per trade for the European markets, 2 points for the Dow and 10 for

the Nikkei. Thus if a system made a PL of 1000 but it required 2000 trades at 2 points per trade, in reality the system would have lost money.

The results presented in this chapter and the following one are based around trading systems. Essentially the methodology concerned, technical analysis in this chapter and time series analysis in the next, attempt to predict future market direction. The values from the various indicators and forecast techniques are fed into a variety of trading algorithms which use the forecast information to decide whether to make long (expect the market to rise) or short (expect the market to fall) trades. For consistency the algorithms all return the same data object containing the following results:

1. Mkt - the name of the financial market such as DAX, FTSE etc.
2. S Loss - the value of any stop loss applied
3. LongPL - the profit or loss generated from just the “Long” trades.
4. ShortPL - the profit or loss generated from just the “Short” trades.
5. L Win % - the percentage of time the Long trades win.
6. L Trades - the number of Long trades executed.
7. Av L PL - the average profit or loss generated from each Long trade.
8. S Win % - the percentage of time the Short trades win.
9. S Trades - the number of Short trades executed.
10. Av S PL - the average profit or loss generated from each Short trade.
11. misc - miscellaneous information such as the SMA used in the algorithm.

The results from Long and Short trades in particular trading algorithm are considered separately as frequently markets behave differently as they move up as opposed to as they fall. Further, the percentage of times the algorithm results in winning trades, the number of trades and the average profit or loss (PL) for each trade is reported for both Long and Short trades. The average PL is primarily reported in the following results tables because this allows comparisons between systems that generate a lot of trades with those such as the algorithms based on candlestick patterns that results in only a small number of trades.

## 4.2 Baseline Systems - Naive Methods

Initially two very simple ideas were explored in order for the results to be used as baselines against which the technical indicators explored in the rest of the chapter and the time series models of Chapter 5 can be compared. There is an expectation that the use of technical indicators will produce systems that provide much better results than these two so-called naive systems.

The first system simply uses the idea that markets tend to increase in value over time. The algorithm applies a naive approach and simply enters a trade each day expecting the market to rise. The well-known method of "Buy and Hold" applies the same principles. The total PL of the resulting system is the the sum of all the daily close minus open prices. This approach has been named a "Naive Long System".

The second approach is equally simplistic, and again is based around opening and closing a trade each day. A notable difference from the first naive system is that the algorithm can result in either a buy or a sell (expecting the market to decline in value) occurring. If a market increased in price the previous day the algorithm "reverses" it and expects the market to fall today. Likewise if the market had fallen the previous day the system buys the market today. This idea has been named the "Naive Reversing System".

### 4.2.1 Naive Long System

The results of the naive long system can be seen in Table 4.1. The R code for the algorithm which generates the results shown in Table 4.1 can be seen in Appendix A section A.1.2.1. For comparison purposes, the opening prices of the indices in January 2000 along with the closing prices in 2013 can be seen in Table 4.2. In this period three of the indices increased in value (DAX, Dow and AORD) and three decreased (FTSE, CAC and Nikkei).

Interestingly, the PL produced from the Naive Long System doesn't match the price differentials seen in Table 4.2. The German DAX indice produced a marked loss in the naive system even though it actually increased 37% during this period. The Japanese Nikkei declined by over 2600 points in this period, whereas the system reported a loss of over 18000 points in the same period. On the other hand the US Dow increased by around 5000 points during the period of the study but the trading algorithm produced a positive result of almost 10000. These discrepancies can be explained by the fact that the system was using prices from the market's opening to closing times, which represents approximately eight hours of trading between 8am and 4pm local time. These price movements don't account for the rest of the hours, the so-called out of market hours,



when the market prices also change. Clearly the markets show different characteristics in the amount they move during market hours compared to out of market hours. The Nikkei, DAX and CAC have a tendency to fall during market hours and rise during out of market hours. The opposite situation occurs for the Dow.

TABLE 4.1: Naive Long System. A very simple system in which the algorithm assumes the market will rise and enters a long trade each day.

Mkt	LongPL	L Win %	Av L PL
DAX	-1714	52	0
CAC	-6725	50	-2
FTSE	149	51	0
Dow	9816	53	3
Nikkei	-18125	49	-5
AORD	972	52	0

TABLE 4.2: Prices of six national indices in January 2000 and December 2013.

Date	Start 2000	End 2013	Difference	% Change
DAX	6961	9552	+2591	+37
CAC	6024	4250	-1774	-29
FTSE	6930	6749	-181	+3
Dow	11501	16576	+5075	+44
Nikkei	18937	16291	-2646	-14
AORD	3152	5353	+2201	+70

Altering the algorithm slightly so that a trade represents the difference between the previous closing price and today's closing price affects the results markedly. A full 24 hour period is now accounted for and the system reflects the overall market movement during this period. These results can be seen in Table 4.3 and the amended R code can be seen in Appendix A section A.1.2.2.

TABLE 4.3: Naive Long System changed such that the trading period is the previous close price minus today's close.

Mkt	LongPL	L Win %	Av L PL
DAX	2649	53	1
CAC	-1667	51	0
FTSE	86	51	0
Dow	5219	53	1
Nikkei	-2712	51	-1
AORD	2229	53	1

### 4.2.2 Naive Reversing System

The second naive method is to reverse the previous day's movement. For example, if the market closed up the previous day the algorithm follows this by trading short for the current day (the R code for this algorithm can be seen in Appendix A section A.1.2.3). The results from this system can be seen in Table 4.4.

TABLE 4.4: Results from a naive trading system which simply trades in the opposite direction to the previous day's movement.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	947	3131	53	1	49	2
CAC	940	7810	53	1	53	4
FTSE	4284	4115	53	3	50	2
Dow	15799	6047	56	10	49	3
Nikkei	2324	20486	51	1	54	12
AORD	1264	237	53	1	48	0

For all the markets tested, this second naive system produces positive results especially for the Nikkei and CAC trading short and the Dow trading long. These results demonstrate that markets have a tendency to reverse direction each day, they move up one day then down the next. This behaviour is also observed in trending markets, and market “pull-backs” are a well-known phenomena.

### 4.2.3 Summary of Naive Baseline Systems

Of the two naive systems tested, the “reversing” methodology produces the best results in terms of profit and loss by quite a margin. Thus the results from the “Naive Reversing System” will be used to compare the performance of technical indicators being tested in the following sections.

## 4.3 Trend Detection Indicators

One of the most widely used phrases in financial trading is “the trend is your friend”. Thus, most market participants are interested in identifying the start of trends, their direction and strength. In this section a variety of technical indicators that purport to assist in this important task are tested.

### 4.3.1 Simple Moving Average (SMA) System

One of the most popular and widely utilised technical indicators is the simple moving average (as detailed in Chapter 2 section 2.2.1.1). The effectiveness of SMA as an aid to predicting future market movements has been widely debated, with views mixed. A system based on simple moving averages is presented here, and the R code used to generate the results can be seen in Appendix A section A.1.3.1. The algorithm trades daily, opening and closing a trade each day. If the market opens above the SMA the algorithm trades long and trades short when the market opens below the SMA.

Table 4.5 lists the results from passing a variety of national index data sets (see Chapter 3 for details) to the algorithm. For each indice the algorithm is run with values of 5, 25, 50, 100 and 200 for the SMA period. In general the results are poor, especially after consideration is given to any transaction costs. The CAC and Nikkei produce negative results for long trades, the FTSE negative results across the board, and the Dow negative returns on the short side.

One aspect of a trading system of this nature worth considering is the risk / reward profile. As written in its current form the SMA algorithm has an unlimited profit potential (trades are left to run until the end of the day) and an unlimited potential loss for the same reason. Often traders employ what is known as a “stop loss”. This is a level in the market that if reached during a trade will cause the trade to close. The risk is now therefore reduced to this value while the profit is still potentially uncapped. Table 4.6 lists the results of using a stop loss with the SMA system.

The logic of the stop loss was coded as follows. Considering a long trade (the opposite holds true for trading short), where there is an expectation that the market will rise, a the stop loss would be triggered if the market fell to a certain level. Thus in the algorithm for a long trade the distance from the opening price to the low is calculated and this is compared to the stop loss value. If the open to low value exceeds the stop loss value the PL for this particular trade is set at the stop loss value, for example a loss of 100 points. One point of note is the fact that after hitting this low level the market may well recover and move upwards as originally expected. In many cases a trade that ultimately would have been profitable may be “stopped out” by the natural wax and wane of the markets. Therefore the impact of a stop loss is the balance between lost good trades and the reduction in the lost PL from losing trades. The size of the stop loss determines the impact of the two competing situations.

Figure 4.1 shows the situation in which a stop loss is beneficial. The potential large loss is reduced to the value of the stop loss value. Figure 4.2 illustrates the alternative scenario of being “Stopped Out” of an ultimately winning trade, an undesirable outcome.

TABLE 4.5: Results from a system based on SMA.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL	misc
DAX	2113	3278	54	1	50	2	SMA 5
DAX	1367	3427	54	1	50	2	SMA 25
DAX	779	3447	54	0	51	3	SMA 50
DAX	714	2339	54	0	51	2	SMA 100
DAX	3401	4416	55	2	52	4	SMA 200
CAC	-3952	2338	49	-2	49	1	SMA 5
CAC	-5058	1615	49	-2	49	1	SMA 25
CAC	-5323	1029	49	-3	49	1	SMA 50
CAC	-2363	3188	50	-1	50	2	SMA 100
CAC	-1219	3923	50	-1	50	3	SMA 200
FTSE	-4724	-5331	49	-2	46	-3	SMA 5
FTSE	-1013	-1940	51	0	47	-1	SMA 25
FTSE	-2226	-2769	50	-1	47	-2	SMA 50
FTSE	-889	-1692	51	0	48	-1	SMA 100
FTSE	-158	-835	52	0	49	-1	SMA 200
Dow	408	-9630	52	0	46	-6	SMA 5
Dow	1138	-9204	53	1	46	-7	SMA 25
Dow	5478	-5876	53	3	47	-4	SMA 50
Dow	2576	-8220	53	1	47	-6	SMA 100
Dow	6378	-4567	54	3	48	-4	SMA 200
Nikkei	3078	20401	51	2	54	13	SMA 5
Nikkei	-7878	10770	48	-4	52	7	SMA 25
Nikkei	-6054	11408	49	-4	52	7	SMA 50
Nikkei	-6235	8381	49	-4	52	5	SMA 100
Nikkei	-5928	6836	49	-4	52	4	SMA 200
AORD	5009	3929	55	3	51	3	SMA 5
AORD	3701	2674	54	2	50	2	SMA 25
AORD	2804	1864	54	1	50	1	SMA 50
AORD	2688	1521	54	1	50	1	SMA 100
AORD	2574	1616	54	1	51	2	SMA 200

It is the ratio of these scenarios that ultimately determines whether using a stop loss is a sound strategy.

Comparing Tables 4.5 and 4.6 it can be seen that applying the stop loss has been on the whole beneficial to the results obtained, with the exception of those from the Dow which were markedly negatively impacted. Essentially losing trades have been truncated while winning trades have been left to develop. One question that needs to be addressed is what value is appropriate for a stop loss. If the value is large the benefits of cutting losses is lost, whereas if it is too small a large number of trades will be “stopped out”. Many traders use a value based on the Average True Range (see Chapter 3 section 3.2.1 for details) as this allows for the volatility of a particular market.

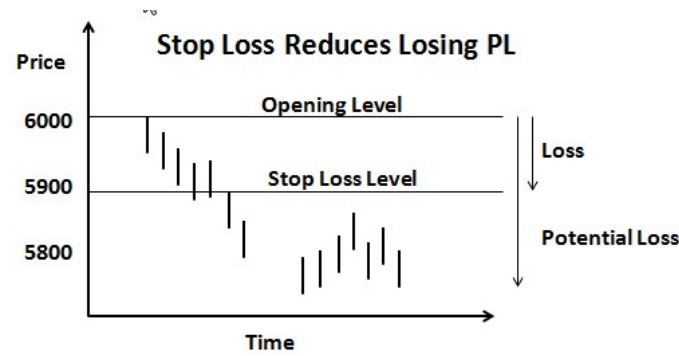


FIGURE 4.1: Situation in which using a stop loss is beneficial, with a losing PL being reduced.

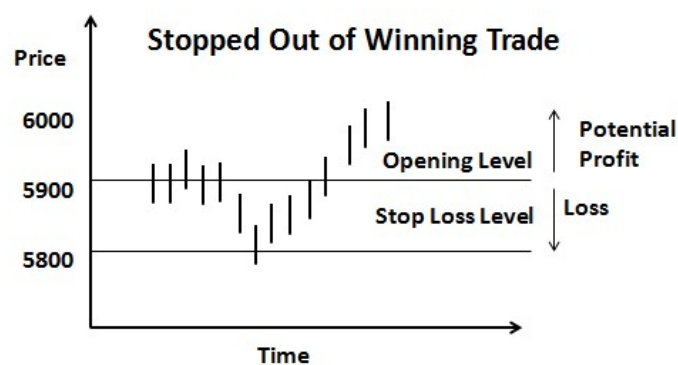


FIGURE 4.2: Situation in which using a stop loss is detrimental, being “stopped out” of an ultimately winning trade.

### 4.3.2 Moving Average Convergence/Divergence (MACD)

Moving Average Convergence/Divergence (MACD) is a trend following indicator, developed by Appel (2005), that is formed from the relationship of two moving averages, see Appendix B section B.1 for more details. The value of MACD itself is the difference between two exponential moving averages (EMA), a “slower” e.g. 26 day value and a “faster” e.g. 12 day value. In addition an EMA of the MACD value is calculated, which is set to 9 days in the following algorithm, which acts as a “signal” line.

The MACD is generally used two ways. Firstly, it can be used to derive the general trend of the security so that the market participant can trade with the trend. Secondly, it can be employed to identify periods when the market is “over-bought” or “over-sold” and can be expected to reverse direction (Achelis, 2014).

In order to identify the trend of a market using the MACD indicator, the relative values of the MACD itself and the signal line are used. If the value of the MACD exceeds the signal it is considered “bullish” and the market is expected to rise in price. Similarly in

TABLE 4.6: Results from a system based on SMA with stop loss.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL	misc
DAX	3652	6618	51	2	42	5	SMA 100
DAX	1392	5272	54	1	50	4	SMA 100
CAC	-172	5178	50	0	47	4	SMA 100
CAC	-1822	4658	50	-1	50	3	SMA 100
FTSE	1114	6303	50	1	43	5	SMA 100
FTSE	-885	1892	51	0	47	1	SMA 100
Dow	-18212	-8229	32	-9	22	-6	SMA 100
Dow	-11771	-14696	49	-6	36	-11	SMA 100
Nikkei	8258	33882	38	5	39	20	SMA 100
Nikkei	2550	25582	47	2	48	15	SMA 100
AORD	4008	3730	54	2	49	3	SMA 100
AORD	2881	2149	54	1	50	2	SMA 100

the opposite situation where the value of the signal is greater than the MACD the trend of the market is expected to be down.

Table 4.7 lists the results of using the MACD indicator in just such a way. The MACD value itself is generated using the EMA of the opening prices with values of 26 and 12 for the slow and long averages and a value of 9 days for the indicator line.

The trading algorithm splits the results into two values, days when the system expected the market to rise and days when a market decline were predicted (see Appendix A section A.1.3.2 for details of the R code used). At the start of each day if the MACD value exceeds the signal line the algorithm adds the value of the close price minus the opening price to the “Long PL” running total. Likewise in the opposite situation with the signal line greater than the MACD, the value of the open price minus the close price is added to the “Short PL”. Table 4.7 lists the results of the algorithm run against a variety of national indices.

TABLE 4.7: Results from a system using MACD as a trend indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-791	1424	53	0	48	1
CAC	-4153	2188	49	-2	49	1
FTSE	63	-839	51	0	48	0
Dow	5592	-5190	53	3	46	-3
Nikkei	-4078	14064	49	-2	52	8
AORD	2563	1569	54	1	49	1

### 4.3.3 Aroon Indicator

Developed by Tushar Chande, the Aroon indicator was designed to identify trending markets (Chande and Kroll, 1994). The word aroon means “dawn’s early light” in Sanskrit and this indicator tries to pin point the dawning of a new trend. Essentially it is a measure of the time since the occurrence of a high/low price in a particular period. Further details can be seen in Appendix B section B.2.

TABLE 4.8: Results from a system based on the Aroon indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	5308	5257	56	3	51	4
CAC	-1638	4919	50	-1	52	4
FTSE	3042	5715	52	2	51	5
Dow	12131	3811	55	7	49	3
Nikkei	-4852	12013	49	-3	52	10
AORD	3735	3540	55	2	50	3

Table 4.8 shows the results of applying the Aroon algorithm (shown in Appendix A section A.1.3.3) on the data of the national indices. The results are promising with the indicator making positive predictions in most of the markets and doing particularly well in declining markets.

TABLE 4.9: Results from a system based on the Aroon indicator with stop loss.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	5410	7465	56	3	50	6
CAC	-1224	6086	50	-1	52	5
FTSE	3091	8015	52	2	51	7
Dow	-5922	-9341	49	-3	37	-8
Nikkei	3153	22177	46	2	47	18
AORD	3786	4159	55	2	50	4

The affects of using a stop loss with the Aroon indicator was investigated and the results shown in Table 4.9. The use of a stop loss was beneficial in all cases except the Dow, in which case it had a catastrophic impact turning a winning system into a losing one. The impact of the stop loss is shown in Table 4.10 which lists the difference in PL between the original results without a stop loss and the revised ones with it.

## 4.4 Market Reversal Indicators

The alternative to trend detection indicators are market reversal indicators, designed to identify when a trend may be ending and the market will start to move in the opposite

TABLE 4.10: Impact of using stop loss with Aroon trend indicator.

Market	Long Difference	Short Difference
DAX	102	2208
CAC	414	1167
FTSE	49	2300
Dow	-18053	-13152
Nikkei	8005	10164
AORD	51	619

direction. Many traders advocate that this type of trading should be avoided and cite the old phrase “never try to catch a falling knife”. Nevertheless a variety of market reversal technical indicators are explored and their effectiveness noted.

#### 4.4.1 Parabolic Stop-and-Reverse (SAR)

The parabolic stop-and-reverse (SAR) is a method to calculate a trailing stop. This technical indicator was developed by J. Welles Wilder and is detailed in his book *New Concepts in Technical Trading Systems* (Wilder, 1978). A trailing stop is related to the stop loss explored previously but differs in that it is adjusted as the market moves. The level of this of kind of stop loss is amended periodically such that it is a certain amount away from the high or low value of a market. As the the market makes new highs it is adjusted up or down if the market makes new lows. The parabolic SAR calculates the point at which a long trade would be closed and a short position entered, the assumption being that the market participant is always in the market either short or long. More details on the theory and calculations to generate the parabolic SAR can be found in Appendix B section B.3.

Table 4.11 lists the results from passing a variety of national index data sets to an algorithm using the parabolic SAR. The R code used to generate these results can be seen in See Appendix A section A.1.4.1. On the whole the results from these initial tests are very disappointing. Only three of the national indices generated positive results and only the Japanese Nikkei provided reasonable returns.

#### 4.4.2 MACD as reversal Indicator

MACD can also be used as a reversal indicator. Recalling that the MACD is formed from the relationship of two moving averages, when the faster one moves sharply away from the slower one (i.e.the value of MACD rises) this could be an indication of an “over-bought” market and that a reversal is approaching. In this situation the trader would



TABLE 4.11: Results from a system based on the SAR indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-3856	-2353	53	-2	48	-2
CAC	-5584	1034	49	-3	49	1
FTSE	-1141	-1663	51	-1	48	-1
Dow	-1301	-11112	52	-1	46	-7
Nikkei	-5767	12424	49	-3	52	8
AORD	2071	1097	53	1	49	1

place a sell trade. The opposite is true for a large negative MACD, and it is postulated that the market may well reverse upwards.

Table 4.12 shows the results of applying the algorithm shown in Appendix A section A.1.4.2 on the data of the national indices. In the algorithm the 15% and 85% quantile of the MACD value is calculated and this is used to decide on the reversal point. Once the 85% value is exceeded the algorithm predicts a reversal will occur and trades short, the opposite is true for the 15% level which triggers a long trade. Overall the results are very modest, with small positive gains being seen in 5 of the 6 national indices.

TABLE 4.12: Results from a trading system based on MACD being used as a trend reversal indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	391	407	49	1	48	1
CAC	-545	2657	51	-1	55	5
FTSE	2080	1649	53	4	53	3
Dow	3882	-807	52	7	48	-2
Nikkei	199	2828	51	0	52	6
AORD	-319	-584	50	-1	49	-1

## 4.5 Momentum Indicators

Momentum indicators are closely related to the trend indicators introduced in section 4.3. They are concerned with trending markets but differ in that the strength of the trend is also included in the information the indicator attempts to portray.

### 4.5.1 Stochastic Oscillator

The stochastic indicator is one of the oldest in widespread use today having been developed by George Lane in the 1950s (Lane, 1986). It measures the relative position

of a market's closing price in the range between the low and high of the period of interest. This is of interest as some market participants believe that financial markets essentially swing between price boundaries marked by where the market closes in this range (Williams, 2011). Thus markets increase until the close is at the top of this range before changing direction and moving down until it is at the bottom of the high low range.

The stochastic is usually represented by two lines %K which is the position of the price within this high low envelope described above, and %D a moving average of %K (see Appendix B section B.4 for more details). It can be used a number of ways and one popular technique is to go long when the %K crosses above %D and to go short in the opposite situation. Table 4.13 lists the results from passing a variety of national index data sets to an algorithm which uses the relative position of %K and %D to decide which way to trade. The R code used to generate these results can be seen in See Appendix A section A.1.4.3.

TABLE 4.13: Results from a system based on the Stochastic indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-28	1673	53	0	49	1
CAC	-4540	1817	48	-3	48	1
FTSE	-73	-744	51	0	48	0
Dow	867	-9414	53	0	46	-5
Nikkei	-10591	7802	48	-6	51	5
AORD	2839	1780	54	2	49	1

The results from Table 4.13 for this system are very modest with only the Australian ORD showing positive values for both long and short trades. Adding a stop loss of 100 points increases the PL across the board except for the case of the Dow where again the stop loss has had a detrimental affect. The results from using a stochastic based system with a stop loss can be seen in Table 4.14.

TABLE 4.14: Results from a system based on the Stochastic indicator with a stop loss.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	1173	3889	52	1	48	2
CAC	-3493	2730	48	-2	48	2
FTSE	1640	1424	51	1	48	1
Dow	-13969	-27388	45	-8	37	-16
Nikkei	1647	17977	45	1	46	10
AORD	3028	1974	54	2	49	1

### 4.5.2 Rate of Change (ROC)

The Rate of Change (ROC) indicator is a simple and widely observed technical indicator. It is the difference between the current price and the price several observations ago. See Appendix B section B.5 for details. If this value is large, either positive or negative it is indicative of a strongly trending market with a lot of momentum either upwards or downwards. The R code for a trading system exploiting these ideas can be seen in Appendix A section A.1.4.4. The results can be seen in Table 4.15 which lists the results from passing a variety of national index data sets to the algorithm.

TABLE 4.15: Results from a system based on the ROC indicator.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	1026	180	50	2	50	0
CAC	952	956	53	2	51	2
FTSE	1147	1880	51	2	51	4
Dow	8517	3396	58	16	49	6
Nikkei	2971	2546	50	6	52	5
AORD	271	1325	51	1	52	2

## 4.6 Break-out systems

This section explores some trading systems that use a particular price as the indicator to place a trade. The first system uses the simple idea of trading when the previous day's high or low is passed. The second idea is related to the results generated in Chapter 3, where the 90% quantile for the day's minor move was calculated. The system tested here is to simply trade long or short when this point is reached in a day.

### 4.6.1 Daily High / Low Breakout System

Table 4.16 lists the results from a trading system based around the idea of trading after the previous day's high or low price has been breached. The R code used to generate these results can be seen in See Appendix A section A.1.5.1.

Referring to Table 4.16 we can see that this system produces good results, with the exception of the US Dow. This ties in with the data in Chapter 3 Table 3.6 which shows that the Dow only closes outside of the previous low or high price a relatively low number of times. Likewise good results are seen with the Japanese Nikkei from the breakout system and this tallies with the high proportion of the time in which it closes above or below the previous day's high or low.

TABLE 4.16: Results from the Daily High / Low Breakout System.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	12225	13411	55	7	54	8
CAC	3491	6955	53	2	53	4
FTSE	13189	18481	59	7	59	12
Dow	-19598	-28337	42	-11	38	-17
Nikkei	31988	43554	57	19	58	27
AORD	17225	19184	66	10	65	13

#### 4.6.2 Break Out of 90% Quantile Level

A second system utilising the break-out concept is presented in this section. In Chapter 3 one characteristic of the markets was noted, namely that each day the market moves from its opening price to a low price and then to a high price (not necessarily in any particular order). One of these moves (O-H vs O-L) is greater than the other was termed the major move and the smaller move was called the minor move. The algorithm generating the results in this section (see Appendix A section A.1.5.2) makes a long or short trade after the market has passed the 90% quantile of the minor move. Table 4.17 lists the results from this algorithm.

TABLE 4.17: Results from a system that breaks out from the 90% quantile level of the day's minor move.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	7841	6371	56	6	53	4
CAC	2647	5085	54	2	52	3
FTSE	10758	15295	56	7	54	10
Dow	-30262	-34854	39	-24	37	-28
Nikkei	23606	31830	58	16	56	20
AORD	16730	19357	63	9	62	12

## 4.7 Candlestick Patterns

As previously noted in Chapter 2 section 2.1.5 candlestick patterns are visual representations of price movements over the course of a particular time period (often a day) in terms of the market's opening, closing, high and low prices. The pattern generated from these price markets are categorised and named depending upon the visual shape they produce. Thus candlestick patterns represent the counter forces of buyers and sellers throughout the trading period. This section analyses some well known candlestick patterns for predictive power in making trading decisions (Lu, 2014).

### 4.7.1 Hanging Man, Hammer, Inverted Hanging Man and Shooting Star

Four well-known patterns that are generally considered to indicate the possible end of a trend and the start of a reversal are the so-called Hanging Man, Hammer, Inverted Hanging Man and Shooting Star candlestick patterns.

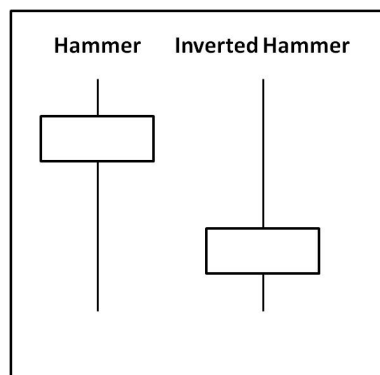


FIGURE 4.3: Hammer and Inverted Hammer candlestick patterns.

Figure 4.3 is a diagram of a Hammer and Inverted Hammer patterns. Both patterns have a small “body” (the distance between the open and close prices) and a long “shadow” (the distance between the high and low prices). In the diagrams presented here a white candlestick means the market price increased over the course of the day while a black one means the market fell. The body of the candlestick is white in this case, indicating that the market moved up (the closing price was above the opening price), although by only a small amount. Hammer and Inverted Hammer differ in that the long shadow in hammer is generated from a low price whereas the shadow of Inverted Hammer goes upwards as it is indicative of the period’s high price.

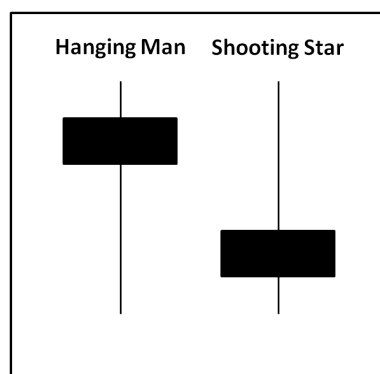


FIGURE 4.4: Hanging Man and Shooting Star candlestick patterns.

Figure 4.4 is a diagram of Hanging Man and Shooting Star, these being the opposite to Hammer and Inverted Hammer. In this case the market direction is down, albeit only by a small amount, and thus the body of the candlestick is a different colour, in this

case black. Again both patterns have long shadows, the direction of which determines if the pattern is Hanging Man or Shooting Star.



FIGURE 4.5: Daily candlestick patterns from the German DAX over 22 days in April 2014 with Shooting Star and Hanging Man circled.

Both sets of patterns Hammer/Inverted Hammer and Hanging Man/Shooting Star are considered to indicate that a trend is coming to a close and a reversal could be looming. In the case of Hammer/Inverted Hammer if they are encountered during a down trend they could indicate that the selling pressure is easing and a market move to the upside could happen soon. The opposite is true for Hanging Man/Shooting Star. When these are encountered in an up trend they often indicate that the trend is ending and a reversal may occur. Figure 4.5 shows daily candlestick patterns for the German DAX over 22 days in April 2014. A Shooting Star is circled on the 6th April and a Hanging Man on the 23rd April. In each case they occur while the market is rising and in each case it reverses immediately afterwards.

In order to have a system based on candlestick patterns, the pattern itself must be identified in code. A Hammer and Hanging Man are essentially the same pattern except Hammer has a close higher than the open whereas Hanging Man represents a decline in the price. For these patterns three components are defined, the length of the upper shadow (short), the size of the body (short) and the length of the lower shadow. In the trading system that follows these were defined as:

1. Upper Shadow - the value of the day's high minus the high of the body is less than 10% the total High-Low range.
2. Body - is larger than 10% the total High-Low range.
3. Lower Shadow - the value of the day's low minus the low of the body is greater than 66% of the High-Low range.

Analysing the DAX data set running from 2000 to 2013 with 3570 observations, and using the criteria described above 35 Hammer and 48 Hanging Man patterns can be detected.

Inverted Hammer and Shooting Star are again the same pattern except in Inverted Hammer the price rose. In the later system these are defined as:

1. Upper Shadow - the value of the day's high minus the high of the body is at least 66% the total High-Low range.
2. Body - is larger than 10% the total High-Low range.
3. Lower Shadow - the value of the day's low minus the low of the body is less than 10% of the High-Low range.

Considering the DAX data set again, occurrences of these patterns are quite rare with 30 Inverted Hammers and 17 Shooting Stars in 3570 observations.

Results from a trading system based on the Hammer / Inverted Hammer can be seen in Table 4.18 and the R code in Appendix A section A.1.6.1. The algorithm simply places a buy the day after a Hammer or Inverted Hammer occur, the assumption being that these patterns indicate that the market is about to rise.

TABLE 4.18: Results from a system based on the Hammer and Inverted Hammer candlestick patterns.

Mkt	LongPL	L Win %	L Trades	Av L PL
DAX	594	53	126	5
CAC	-793	44	149	-5
FTSE	834	58	188	4
Dow	2097	59	88	24
Nikkei	-2202	48	147	-15
AORD	-809	46	236	-3

An alternative approach is to look for Hammer and Inverted Hammer patterns occurring in a down trend, in which case it could signal the end of the down trend and the start of a reversal. Table 4.19 shows the results of using the Hammer and Inverted Hammer to predict a price rise during a down trend. An aroon down value of greater than 65 (with a 20 day look back period) is used to define the down trend. The algorithm can be seen in Appendix A section A.1.6.2.

TABLE 4.19: Results from a system based on the Hammer and Inverted Hammer candlestick patterns occurring in a downtrend as defined by the aroon value.

Mkt	LongPL	L Win %	L Trades	Av L PL
DAX	-187	42	36	-5
CAC	-515	44	55	-9
FTSE	281	55	65	4
Dow	730	55	22	33
Nikkei	-934	48	58	-16
AORD	-614	41	77	-8

### 4.7.2 Engulfing Candlestick

The “Engulfing” pattern, either Bull or Bear is another widely considered candlestick pattern and is depicted in Figure 4.6. This pattern has a lower low and a higher high than the preceding candlestick and is usually interpreted as indicating a change in direction of the trend. Engulfing candlesticks can be either bullish, where the closing price is above the opening price or bearish when the market moves down.

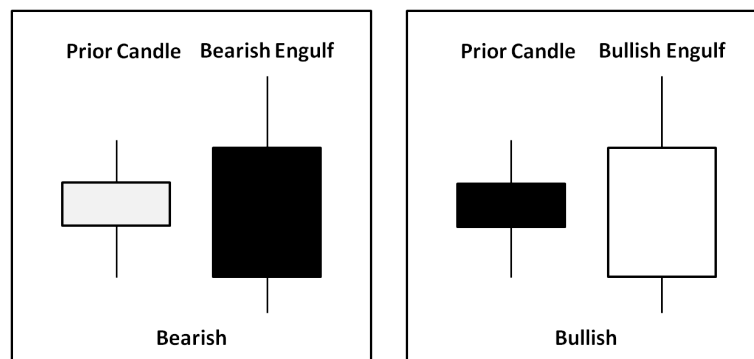


FIGURE 4.6: Engulfing candlestick patterns.

Table 4.20 lists the results from passing a variety of national index data sets (see Appendix A section A.1.6.3 for details) to an algorithm that buys or sells the market depending on the presence of an Engulfing pattern.

TABLE 4.20: Results from a system based on the Engulfing candlestick pattern.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-920	-258	44	-7	46	-2
CAC	-319	228	45	-2	50	1
FTSE	-1721	1185	51	-4	50	3
Dow	-770	-3662	48	-4	35	-28
Nikkei	-3823	-1166	37	-39	44	-11
AORD	-6	-600	53	0	46	-3



Table 4.21 lists the results from extending the algorithm such that trades are only taken in either up or down trends, as defined by the aroon indicator. The R code for the amended algorithm can be see Appendix A section A.1.6.4.

TABLE 4.21: Results from a system based on the Engulfing candlestick pattern in a trending market.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-874	-513	38	-20	43	-7
CAC	-118	-666	49	-3	30	-11
FTSE	-1217	-782	47	-8	48	-3
Dow	202	-1154	45	4	44	-11
Nikkei	-1522	-1733	38	-59	37	-32
AORD	-49	-27	53	-1	50	0

### 4.7.3 Doji

Doji is a well-known candlestick pattern that can appear on its own or as a component of a pattern. A Doji forms when the open and close price are similar and there is an upper and lower shadow, thus they often resemble a cross. Variations within Doji include the Dragonfly and Gravestone Doji, see Figure 4.7. In an up trend Doji (especially Gravestone) can indicate a reversal could occur and likewise in a down trend a Dragonfly could suggest an upward move is about to start.

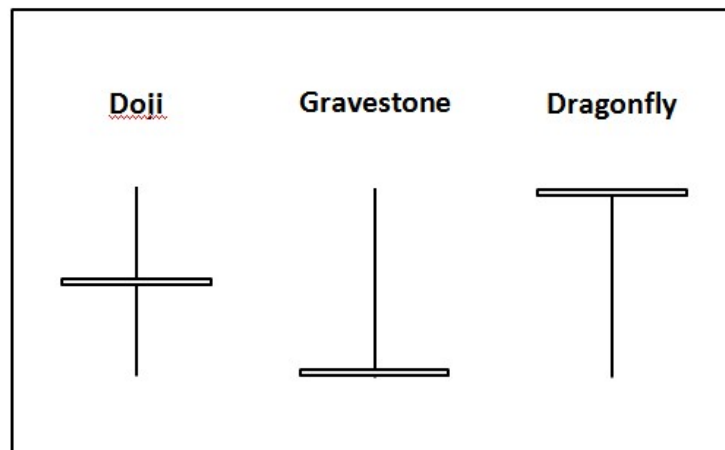


FIGURE 4.7: Doji candlestick patterns.

Table 4.22 lists the results from passing a variety of national index data sets (see Appendix A section A.1.6.5 for details) to an algorithm that buys or sells the market depending on the presence of a Doji. In an up trend, as identified by the aroon indicator, a Doji or Gravestone is used to initiate a sell and conversely in down trend a Doji or Dragonfly is used as a signal to buy.

TABLE 4.22: Results from a system based on the Doji candlestick pattern in a trending market.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-826	-1132	53	-8	52	-6
CAC	-747	-326	46	-6	49	-2
FTSE	-697	418	53	-8	52	3
Dow	-763	-2869	51	-5	50	-10
Nikkei	1296	-2944	55	12	45	-22
AORD	-115	195	54	-1	54	2

## Chapter 5

# Time Series

This chapter will explore the use of time series analysis techniques to generate models for forecasting prices in various national stock market indices. Usually, in trying to predict the future behaviour of financial markets the direction they will move, either up or down, is of more interest than the actual value itself. Thus, in this chapter predictions of the future direction as well as the actual value itself are attempted. A variety of time series models are developed using exponential smoothing, ARIMA and hybrid ARIMA methods.

### 5.1 Exponential Smoothing

Exponential smoothing was applied to the stock market indice data sets in order to generate predictions for the following day's closing price, so-called one step ahead forecasts. Two basic approaches and an exponential smoothing methodology were examined. The two basic methods provide a useful baseline against which to compare later models, and are the mean and drift methodologies. The mean is simply the average of the data points in the sample while the drift is equivalent to drawing a straight line between the first and last point of the sample and then extrapolating this line forward the desired number of observations.

#### 5.1.1 Time Series Base Models

Figure 5.1 shows the two base methods, mean and drift, being applied to a data set derived from the German DAX. The models were trained on the first 3000 observations of the DAX data set and tested on the remaining ones. The actual data points being predicted in Figure 5.1 are added to the plot in Figure 5.2. Five error measures, root

mean square error (RMSE), mean absolute error (MAE), mean percentage error (MPE), mean absolute percentage error (MAPE) and mean absolute scaled error (MASE) for the two methods are listed in Table 5.1. From these error measures we can see that the drift model fits the training data the best, having the smallest error values across all the measures, but that the mean model actually performs the best on the test data.

TABLE 5.1: Error measures from mean and drift models.

	RMSE	MAE	MPE	MAPE	MASE
Mean Training Set	1394	1183	-8	25	1
Mean Test Set	208	163	2	3	3
Drift Training Set	84	61	-0	1	0
Drift Test Set	302	262	-5	5	4

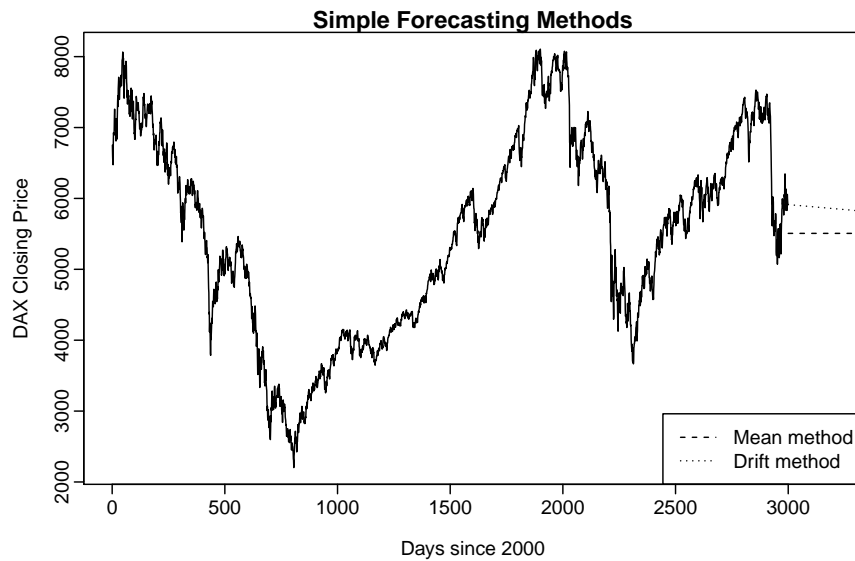


FIGURE 5.1: Forecasts generated by mean and drift methods.

Looking at Figure 5.2 it can be seen that neither the mean or the drift does a good job with the predictions for the DAX. The forecasts were based on the entire data set, treating it as a homogeneous whole. However, financial time series typically show a variety of behaviour at different periods. On occasions it is stationary and at other times trending. Thus, in the following sections, in order to generate forecasts a sliding window approach was adopted. A window of data (the last 30 observations) was used to generate a model and the one step ahead forecast, before the window was advanced one observation to the next period. In this way the model is constantly adapting and changing. Using this approach forecasts and models for use in a trading system from a mean, drift and exponential smoothing methodology were developed.

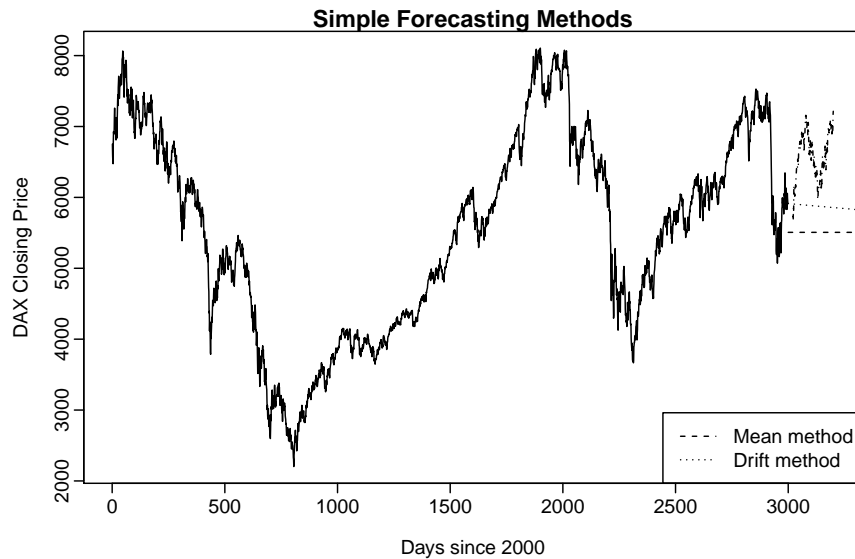


FIGURE 5.2: Forecasts generated by mean and drift methods with actual data in forecast period added.

### 5.1.2 Trading System Based on Mean Model

Results from a trading system using the one step ahead forecasts generated by the mean model using a moving window are listed in Table 5.2. A trading algorithm, which can be seen in Appendix A section A.2.1, used these forecasts to decide in which direction to trade. If the forecast was higher than the closing price a long trade was entered the following day and likewise if it was below the close a short trade was entered.

TABLE 5.2: Results from trading the predictions generated by a mean exponential smoothing system.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-1640	-1505	50	-1	45	-1
CAC	-1086	3553	52	-1	51	2
FTSE	1680	345	53	1	49	0
Dow	8356	-2126	54	7	46	-1
Nikkei	-32	10646	51	0	53	6
AORD	-1333	-2149	50	-1	46	-1

### 5.1.3 Trading System Based on Drift Model

In a similar way to the mean model of section 5.1.2 the predictions generated by the drift model were passed to the trading algorithm and the results can be seen in Table 5.3.

TABLE 5.3: Results from trading the predictions generated by a drift exponential smoothing system.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	2310	2445	54	1	50	2
CAC	-2422	2217	49	-1	48	2
FTSE	-518	-1853	51	0	47	-1
Dow	5416	-5066	54	3	46	-4
Nikkei	-6939	3739	48	-4	50	3
AORD	1476	660	53	1	49	1

#### 5.1.4 Trading System Based on Exponential Smoothing Model

Using Rob J Hyndman's forecast package and the `ets()` function, a variety of exponential smoothing methods can be applied to sample data (Hyndman and Yeasmin, 2008). Table 5.4 lists fifteen possibilities when one combines trend and seasonality, both additive and multiplicative. In fact Hyndman extends this further by allowing the error term to be either added or multiplied against the results.

TABLE 5.4: Taxonomy of exponential smoothing methods.

Trend Component	Seasonal Component		
	N (None)	A (Additive)	M (Multiplicative)
N (None)	(N,N)	(N,A)	(N,M)
A (Additive)	(A,N)	(A,A)	(A,M)
Ad (Additive damped)	(Ad,N)	(Ad,A)	(Ad,M)
M (Multiplicative)	(M,N)	(M,A)	(M,M)
Md (Multiplicative damped)	(Md,N)	(Md,A)	(Md,M)

Using a sliding window approach, one step ahead forecasts were generated using the `ets()` function. Because a different sample of data was contained in each window, the exponential smoothing function selects the best model for each window of data independently of the data set as a whole. Thus the `ets()` function applies a variety of models to the windows of data including:

- ETS(A,N,N)
- ETS(M,N,N)
- ETS(M,A,N)
- ETS(A,A,N)
- ETS(A,Ad,N)

- ETS(M,Md,N)
- ETS(M,Ad,N)
- ETS(M,M,N)

The one step ahead forecasts generated from these models were once again passed to the same trading algorithm listed in Appendix A section A.2.1 and the results can be seen in Table 5.5.

TABLE 5.5: Results from trading the predictions generated by a moving window exponential smoothing system.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-2029	-1894	53	-1	47	-1
CAC	-266	4048	52	0	51	2
FTSE	3866	2531	53	3	50	2
Dow	12901	2419	57	8	50	2
Nikkei	-2741	7937	49	-2	51	5
AORD	645	-171	52	0	48	0

## 5.2 ARIMA Models

The use of Auto-Regressive Integrated Moving Average (ARIMA) models, see section 2.2.4 for details, was explored in order to forecast future prices for financial markets. The process of fitting an ARIMA model to a time series is quite challenging and involves the following general steps:

1. Plot the data to get a general feel for the time series and to establish if it is stationary.
2. Stabilize any variance in the data with a transformation process such as the Box-Cox method.
3. ARIMA models work with stationary data, so if necessary, take differences of the data until it is stationary.
4. Examine the auto-correlation and partial auto-correlation (ACF/PACF) plots in order to determine if an AR(p) or MA(q) model is appropriate.
5. Test the chosen model(s), using the AICc to determine if a better model is available.

6. Check the residuals from the best model by plotting the ACF, and doing a port-manteau test on them. If the results from these tests do not look like white noise, a modified model may be required.
7. Finally, once the residuals have a similar pattern to white noise, the model can be used to generate forecasts.

In recent years automatic forecasting algorithms have become available and are widely used (Hyndman and Yeasmin, 2008). These are necessary in a variety of circumstances, especially when organisations are faced with the need to repeatedly carry out a large number of forecasts and the human effort required renders manual means impractical. The `auto.arima()` function found in R's "forecast" package is an example of an automatic algorithm for ARIMA models. This function automates steps 3, 4, and 5 of those outlined previously, in the general steps required for ARIMA modelling. In the following sections, the general steps are used to generate an ARIMA model manually, and then the automatic algorithm is utilised to build one.

## 5.3 Manual Generation of ARIMA Models

### 5.3.1 Data Exploration

The first step, as always is to explore the data. Figure 5.3 shows the UK's FTSE 100 index between the years 2000 to 2013. Over this time period the series has shown strong trends to move up and down and a uniform variance. Because the time series is non-stationary it will need to be transformed into a stationary series before ARIMA modelling can be undertaken.

### 5.3.2 Adjusting for non-uniform variance and non-stationariness

The variance within the FTSE time series is relatively uniform and thus this data set doesn't need stabilizing with regard to this. If it did, a Box-Cox transformation could be used. However, over this time period the FTSE 100 exhibits marked non-stationariness and requires adjusting accordingly. One such technique to make a data set stationary is differencing. Instead of using the actual observations the differences between two adjacent points are used and this is known as the first difference. If the data set still isn't stationary the difference between consecutive points in the differenced data set can be used, this is the difference of the differences and is known as the second difference. Figure 5.4 shows the FTSE data set after the first differences have been taken. The resulting data set is now stationary.



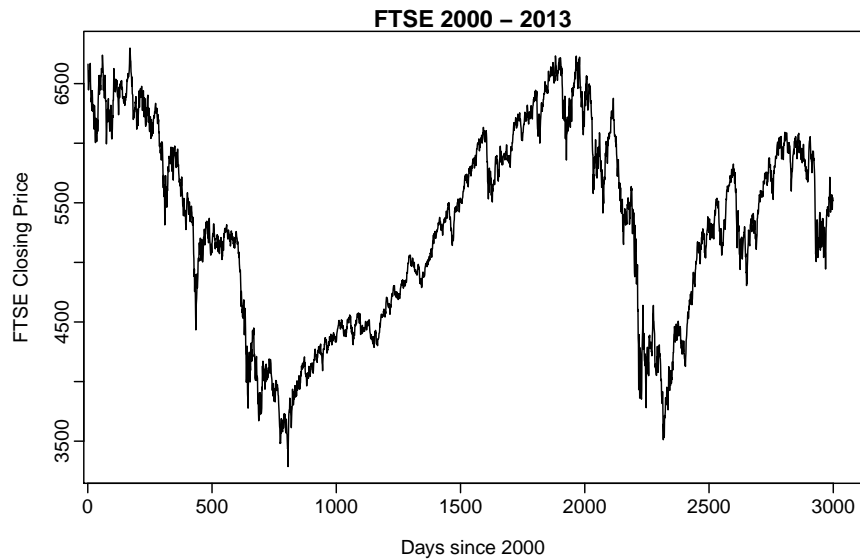


FIGURE 5.3: UK's FTSE 100 index between the years 2000 to 2013.

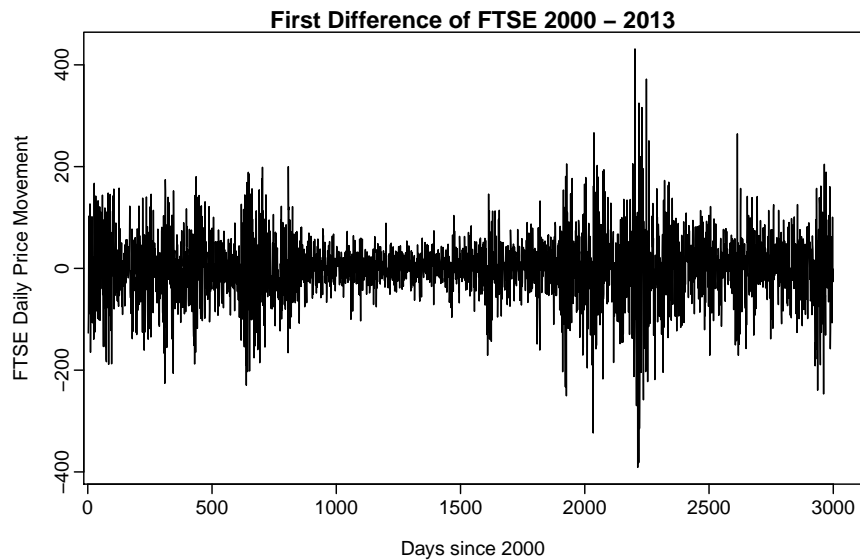


FIGURE 5.4: First difference of FTSE 100 between the years 2000 to 2013.

### 5.3.3 Examine ACF / PACF

With a stationary data set, the next stage is to investigate the auto-correlation and partial auto-correlation (ACF/PACF) plots in order to help in the model selection process (see section 2.2.5 for details of ACF and PACF). The ACF and PACF for the FTSE data set can be seen in Figures 5.5 and 5.6.

If ultimately the ARIMA model is of the form  $\text{ARIMA}(p,d,0)$  or  $\text{ARIMA}(0,d,q)$  then the ACF and PACF plots are useful in helping to define values for  $p$  or  $q$ . In the event that both  $p$  and  $q$  are positive, the ACF and PACF are not helpful in deducing the values for  $p$  and  $q$ . An  $\text{ARIMA}(p,d,0)$  model may be appropriate if the ACF and PACF plots

of the stationary data exhibit an exponentially decaying pattern in the ACF and a large spike at lag  $p$  in PACF plot. Conversely an  $\text{ARIMA}(0,d,q)$  model may be appropriate if the PACF is decaying exponentially and there is a significant spike in the ACF plot at lag  $q$ . Considering the ACF and PACF plots in Figures 5.5 and 5.6, neither of the two patterns are observed and thus an ARIMA model where both  $p$  and  $q$  are positive is likely.

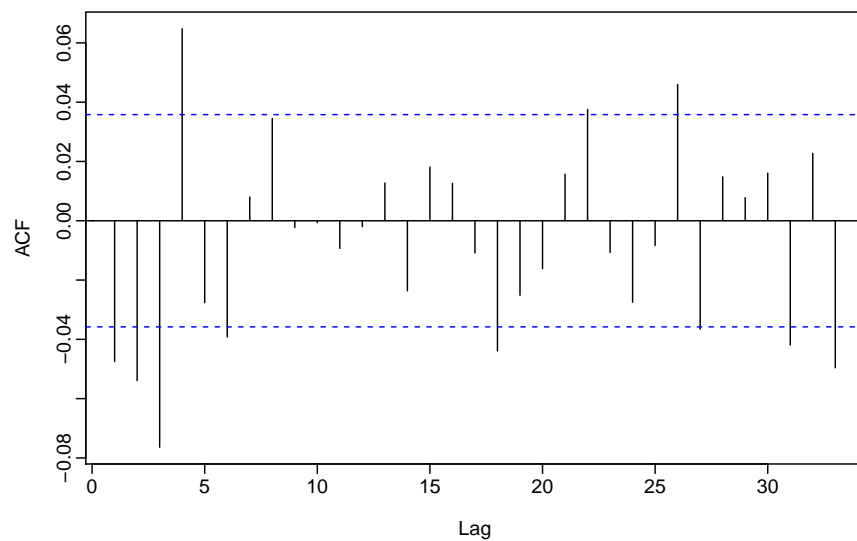


FIGURE 5.5: Auto-correlation plot of differenced data from FTSE 100 between the years 2000 to 2013.

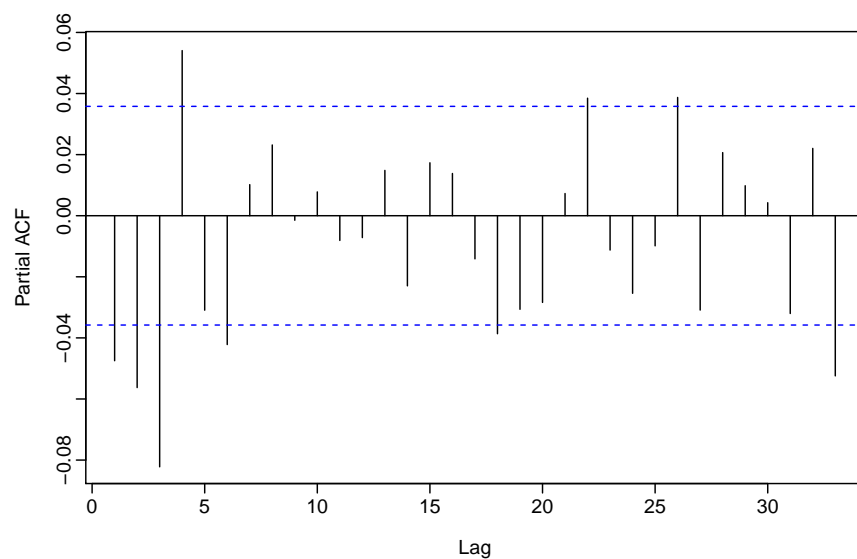


FIGURE 5.6: Partial auto-correlation plot of differenced data from FTSE 100 between the years 2000 to 2013.

### 5.3.4 Try the chosen model(s)

The next step is to try the chosen model along with a few viable alternatives. Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) are useful for determining the optimum order of an ARIMA model, and are typically used as a measure of how well the model fits the data. AIC can be given by:

$$AIC = -2\log(L) + 2(p + q + k + 1)$$

where:

$L$  is the likelihood of the data and  $k = 1$  if  $c \neq 0$  and  $k = 0$  if  $c = 0$ , the last term in parentheses is the number of parameters in the model.

For ARIMA models, the corrected AIC can be written as:

$$AIC_c = AIC + \frac{2(p + q + k + 1)(p + q + k + 2)}{T - p - q - k - 2}$$

The Bayesian Information Criterion can be expressed as:

$$BIC = AIC + \log(T)(p + q + k + 1)$$

Table 5.6 shows the AIC, AICc and BIC accuracy measures for a selection of ARIMA models applied to the FTSE data set. On all three measures the ARIMA(2,1,3) model has the lowest value.

TABLE 5.6: AIC, AICc and BIC results from alternative ARIMA models.

Model	AIC	AICc	BIC
Arima(3,1,1)	33598.5	33598.5	33628.5
Arima(3,1,2)	33594.6	33594.6	33630.6
Arima(3,1,3)	33596.1	33596.1	33638.1
Arima(2,1,1)	33616.4	33616.4	33640.4
Arima(2,1,2)	33618.1	33618.1	33648.1
Arima(2,1,3)	33594.1	33594.1	33630.1

### 5.3.5 Model Residuals

A so-called residual is the difference between an observation and its forecast. In forecasting a time series, residuals are calculated from a one-step forecast. A one-step forecast is based on all observations from the start of the series until the previous observation to which the forecast applies to. Thus the number of data points used to calculate the

one-step forecast increases as the forecast proceeds through the time series. An alternative is cross-sectional forecasting which uses all the points in the data set except the observation being predicted.

Knowledge of the residuals from the application of a model is important in establishing the validity of the model. There are two essential and two valuable properties that can be established by inspecting the model residuals. A good method of forecasting will produce a model in which the residuals are uncorrelated and have a zero mean. If a forecasting method doesn't comply with these two properties it can be improved upon. Correlation in residuals means that information is present in them that the model has missed and a non-zero mean is evidence of bias in the forecast. Adjusting for bias is straight forward, the mean value observed in the residuals can simply be added to all forecasts. Looking at Figure 5.7 it can be seen that the mean of the residuals is close to zero and this model doesn't have any bias. Figure 5.8 is the plot of the residuals of the ARIMA model applied to the FTSE data set. The lower order lags are all within the confidence boundaries and is indicative of a good model.

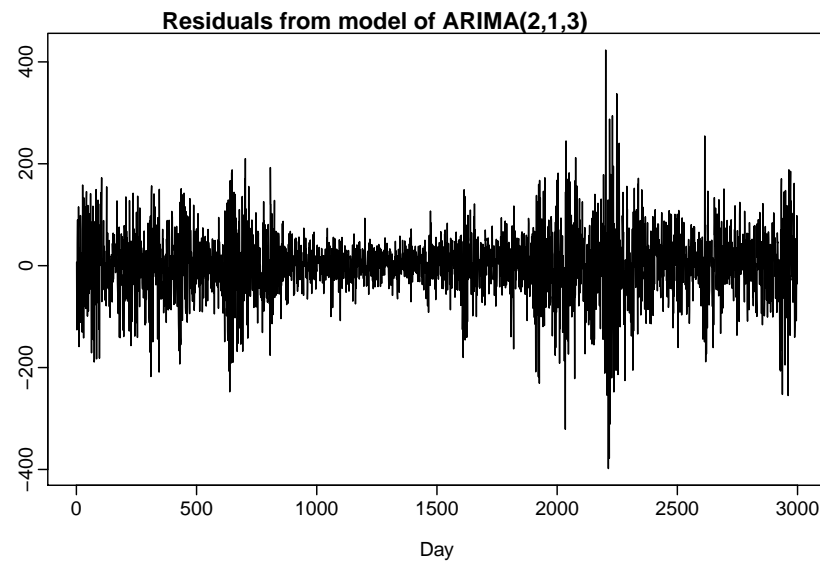


FIGURE 5.7: The residuals after applying the ARIMA(2,1,3) model to the FTSE data set.

Two additional properties of the residuals that are desirable, though not necessary, are constant variance and normal distribution. If these two conditions are met, the calculation of the prediction interval in the forecast step is easier. From Figure 5.7 it can be seen that the residuals have relatively constant variance and from Figure 5.9, a histogram of the residuals, it can be seen that they are normally distributed.

Consideration of the ACF plots provides evidence for auto-correlation. However a more formal approach is to consider auto-correlation values together as a group as opposed to individually. The Box-Ljung portmanteau test is just one such approach and Table 5.7

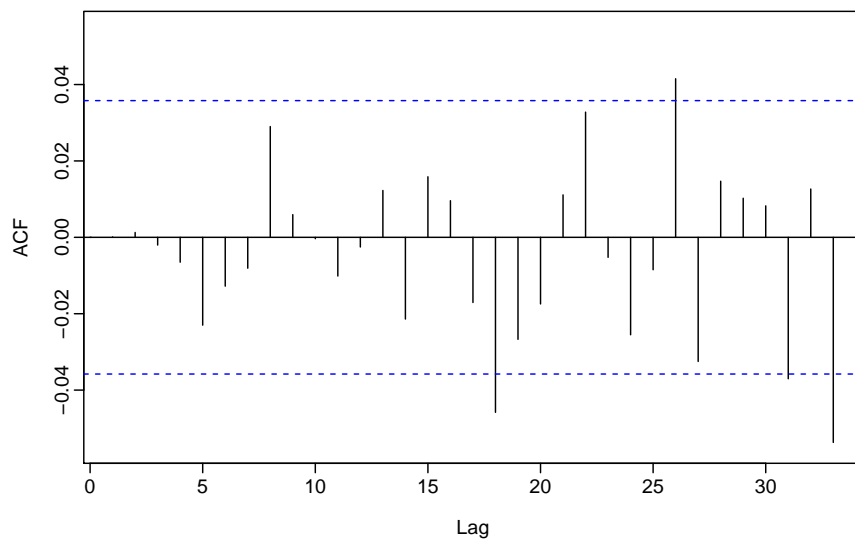


FIGURE 5.8: ACF plot of the residuals after applying the ARIMA(2,1,3) model to the FTSE data set.

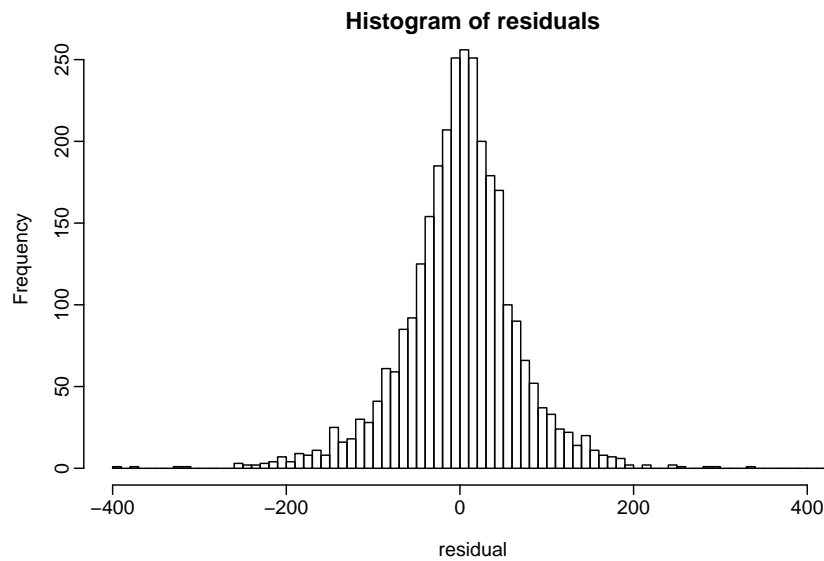


FIGURE 5.9: Histogram of the residuals after applying the ARIMA(2,1,3) model to the FTSE data set.

lists the results of the Box-Ljung portmanteau test being applied to the residuals of the ARIMA(2,1,3) model. A large p-value is indicative of white noise and is the desirable situation for a good ARIMA model. Taking all the evidence together the ARIMA(2,1,3) model appears a good option for the FTSE data set.

TABLE 5.7: Box Ljung test of FTSE 100 ARIMA model residuals.

	p-value	x-squared	df
ARIMA(2,1,3)	0.2328	20	24

### 5.3.6 Calculate forecast

Finally, after developing a model that meets the previous criteria a forecast can be generated. Table 5.8 shows the one-step forecast produced when the ARIMA(2,1,3) model developed in the previous section is applied to the FTSE data set.

TABLE 5.8: One step ahead forecast for FTSE 100 generated from ARIMA(2,1,3) model.

Date	Open	High	Low	Close	Forecast
20/12/2013	6585	6617	6577	6607	6560
23/12/2013	6607	6679	6606	6679	6598
24/12/2013	6679	6712	6672	6694	6666
27/12/2013	6694	6754	6694	6751	6692
30/12/2013	6751	6768	6718	6731	6743
31/12/2013	6731	6757	6731	6749	6730

## 5.4 Automatic Generation of ARIMA Models

As explained previously the automatic ARIMA modelling algorithm in the R forecast package, `auto.arima()`, automates steps 3 to 5 in the general steps used in the modelling process as outlined in section 5.2. The function uses a variation of the Hyndman and Khandakar algorithm which obtains an ARIMA model by the minimisation of the AICc and combination with unit root tests. KPSS tests are used to establish the number of differences,  $d$ , required to get a stationary time series. The  $p$  and  $q$  values are then obtained by choosing the model that minimises the AICc for the differenced data.

The results of passing the indice data sets to the `auto.arima()` function can be seen in Table 5.9. For the FTSE data set the automatic procedure selects the ARIMA(2,1,3) as being the most appropriate, which matches the conclusion of the work from the manual model selection process described earlier in section 5.3.

TABLE 5.9: Arima models chosen to forecast future values in the national indice data sets.

Market	Arima Model
DAX	ARIMA(3,1,3)
CAC	ARIMA(2,1,3)
FTSE	ARIMA(2,1,3)
Dow	ARIMA(1,1,2)
Nikkei	ARIMA(2,1,3)
AORD	ARIMA(1,1,0)

## 5.5 Trading the ARIMA Models

Having developed forecasts based on ARIMA models these can be passed into a trading system. Two ideas are presented here, in the first the previous closing price is compared against the prediction and if it is lower than the forecast a long trade is entered. This first system will be referred to as System 1. In the second algorithm the current forecast is compared with the previous prediction. When the previous forecast value is lower than the current prediction the system trades long. This algorithm will be referred to as System 2.

The data sets containing fourteen years of indice data was divided into a training set, containing the first ten years of data, and a test set holding the remaining four years worth of data. Models were trained on the training sets before being applied to the unseen data in the test sets.

### 5.5.1 System 1 - Close Price vs Forecast

Using the ARIMA models listed in Table 5.9 a series of amended data sets were generated by applying the models to the national indice data sets used throughout this study. The amended data sets contained the original Date, Open, High, Low and Close attributes plus a new one called Forecast, in a similar manner to the data seen in Table 5.8. Table 5.10 are results produced from passing the newly generated data sets to the algorithm listed in Appendix A section A.2.2. This system uses the relative position of the close price and the forecast to determine the direction of the trade. If the forecast is higher than the close a long trade is made and when the prediction is lower than the close price a short trade is made.

TABLE 5.10: Results from trading System 1 using the forecasts generated by the ARIMA models.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-1285	-2522	50	-5	42	-9
CAC	872	167	57	3	51	1
FTSE	990	-249	53	4	46	-1
Dow	1539	-3356	56	7	47	-11
Nikkei	4268	3071	53	21	49	13
AORD	635	-247	55	2	49	-1

### 5.5.2 System 2 - Forecast vs Previous Forecast

Table 5.11 lists the results from passing the amended indice data sets with the forecasts generated from the `auto.arima()` function, described in the previous section, to the System 2 algorithm. The R code of this system can be seen in Appendix A section A.2.3. System 2 uses the relative values of the forecasts themselves to decide which direction to trade. If the prediction is higher than the previous day's prediction a long trade is initiated and in the opposite circumstances when the previous forecast is higher than the current forecast a short trade is made.

TABLE 5.11: Results from trading System 2 using the forecasts generated by the ARIMA models.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	733	-505	55	3	46	-2
CAC	545	-80	53	2	47	0
FTSE	941	-383	54	3	46	-2
Dow	2598	-2221	55	9	46	-10
Nikkei	179	-916	50	1	47	-4
AORD	811	-117	53	3	46	0

## 5.6 Hybrid ARIMA Models

A hybrid ARIMA model is one in which the moving averages of a stationary data set (possibly a non-stationary data set that has been differenced) are combined with data mining learners other than regression. Possible learners include k nearest neighbour algorithms, artificial neural networks and support vector machines. RapidMiner, an open source data mining tool is a powerful solution for building hybrid ARIMA models. Figure 5.10 shows the RapidMiner process used to generate hybrid ARIMA models. The Validation operator in the model below can hold a variety of learners depending upon the task and data types involved. The various components in Figure 5.10 are as follows:

- Read CSV - reads in the appropriate data set.
- Select Attribute (1) - selects the attribute that will be processed in the following steps.
- Rename - renames the attribute selected in Select Attribute (1) to “attr1” which is then used in the rest of the steps. This component is used to make it easy to change the attribute without having to rename all the subsequent steps.



- Moving Average - calculates a moving average of the time series (see section 2.2.1.1 for details.) This provides the q in ARIMA(p,d,q) models.
- Differentiate - calculates the difference in the time series and provides the d in ARIMA(p,d,q) models.
- Lag - creates lag variables which are values of the attribute (the attribute itself, the moving average or the difference value) at earlier points in the time series.
- Select Attribute (2) - selects the attributes that will be passed to the validation block, including the number of previous moving averages and differences.
- Set Role - sets an attribute as the label to be predicted.

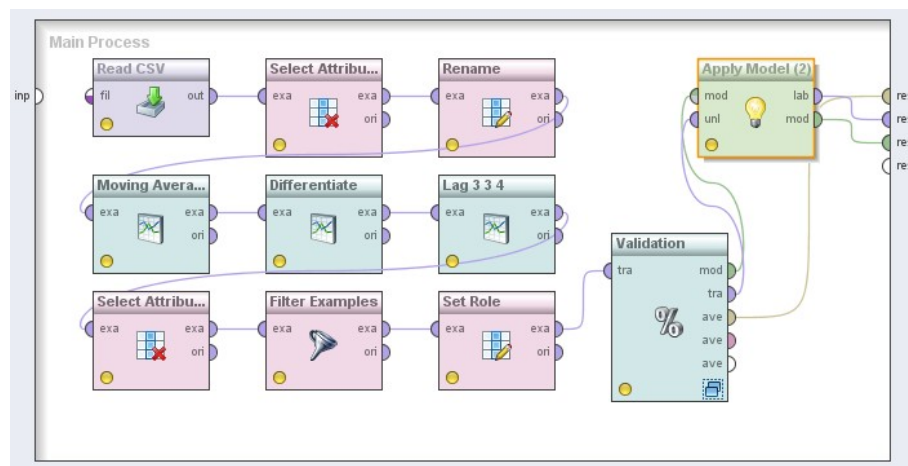


FIGURE 5.10: Rapid Miner hybrid ARIMA process.

Figure 5.11 shows the cross-validation operator of the hybrid ARIMA Rapid miner process. This operator can hold alternative learners other than the standard regression operator found in ARIMA models. In the diagram there is an Artificial Neural Network (ANN) operator shown, other options include k-Nearest Neighbour (k-NN) and Support Vector Machine (SVM) operators.

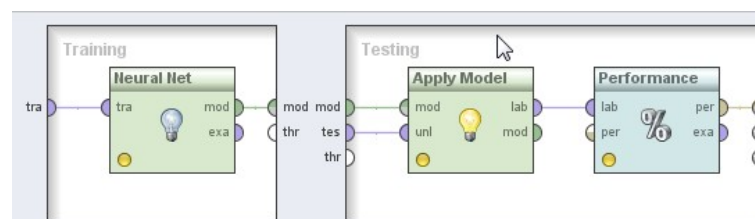


FIGURE 5.11: Rapid Miner cross-validation operator within the hybrid ARIMA process.

## 5.7 Predicting Closing Price

As mentioned previously ARIMA and hybrid ARIMA models were used to predict either the value of the one-step ahead close price or the binary value of whether the market moved up or down. In this section the ability of hybrid ARIMA models to forecast the future price of financial markets (as opposed to the general direction up or down) is explored.

### 5.7.1 ARIMA/Artificial Neural Networks (ANN)

An ARIMA/ANN method was used to generate predictions for the closing price of the indice data sets under study. As described in section 5.6, previous values of the label (closing price), along with past values for the difference and moving averages are passed to an ANN learner within a rapid miner process. Rapid miner implements ANN as a feed-forward neural network trained by back propagation. Feed-forward refers to the fact that information only moves forward from the input nodes to the output neurons. Back propagation is an algorithm in which errors are fed back into the system so that the algorithm can adjust the connection weights between nodes until the error converges to some state. Typically the best results were obtained from using a small learning rate and momentum and using a hidden layer of neurons.

For each data set applying the hybrid model produces a new one-step forecast attribute, in a similar manner to the forecast attribute seen in Table 5.8, which can be used in the System 1 and 2 algorithms previously introduced in section 5.5. Table 5.12 are the results generated by passing the output of the ARIMA/ANN models to trading System 1 (which compares the previous closing price with the current forecast).

TABLE 5.12: Results from passing closing price predictions from hybrid ARIMA/ANN model to System 1.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-446	-645	53	-1	46	-2
CAC	532	1527	55	2	50	2
FTSE	625	-624	51	1	45	-2
Dow	2846	-3979	55	5	45	-9
Nikkei	913	2039	54	2	55	4
AORD	-3036	-371	54	-5	51	-1

Table 5.13 are the results of passing the output of the ARIMA/ANN models to trading System 2, which compares the value of the current forecast with the previous one.

TABLE 5.13: Results from passing closing price predictions from hybrid ARIMA/ANN model to System 2.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	3283	3110	56	6	49	7
CAC	-1832	-816	49	-3	46	-2
FTSE	1092	-182	52	2	48	0
Dow	3829	-2942	54	7	43	-7
Nikkei	-4485	-3229	48	-9	50	-7
AORD	-2783	-137	51	-5	47	0

### 5.7.2 ARIMA/k-Nearest Neighbour (k-NN)

An ARIMA/k-NN method was used to generate predictions for the closing price of the indice data sets. The k-Nearest Neighbour algorithm operates by comparing the current set of attributes to others in the data set and finding ones that are “close” to it. Closeness is usually defined by a distance measure, such as Euclidean, after the attributes have been stored in a n-dimensional pattern space. The k closest neighbours are selected and the most common class of these used to classify the label. In a similar manner to the ANN modelling of section 5.7.1, lag variables of the close price (label attribute to be forecast), moving average and differences of the close price were passed to a k-NN learner in Rapid Miner in order to predict the one-step ahead forecast.

Table 5.14 shows the results of passing data sets containing forecasts generated with the hybrid ARIMA/k-NN to trading System 1. Table 5.15 shows the results of passing data sets containing forecasts generated with the hybrid ARIMA/k-NN to trading System 2.

TABLE 5.14: Results from passing closing price predictions from hybrid ARIMA/k-NN model to System 1.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	12	-174	52	0	45	0
CAC	-684	312	52	-1	50	1
FTSE	699	-550	54	1	50	-1
Dow	4436	-2389	57	11	46	-4
Nikkei	-66	1060	48	0	50	2
AORD	497	3162	53	1	50	7

## 5.8 Predicting Up or Down - Categorical Label

In this section the ability of hybrid ARIMA models to forecast whether a financial market will rise or fall is investigated. A categorical attribute taking values “U” and “D”, representing whether the market moved up (“U”) or down (“D”) was introduced

TABLE 5.15: Results from passing closing price predictions from hybrid ARIMA/k-NN model to System 2.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	489	731	54	1	47	2
CAC	-1458	-441	49	-3	46	-1
FTSE	-388	-1662	50	-1	45	-4
Dow	2969	-3411	54	5	43	-9
Nikkei	-2916	-1660	47	-6	49	-4
AORD	-3449	-804	52	-6	48	-2

into the indice data sets depending upon which way the market moved that day. Hybrid ARIMA models, of the form already introduced, were used to forecast this categorical label.

### 5.8.1 ARIMA/Artificial Neural Networks (ANN)

The R code for a trading system using the forecasts from a hybrid model can be seen in Appendix A section A.2.4. The algorithm simply uses the prediction from the hybrid ARIMA model (“U” or “D”) to decide whether to trade long or short. Table 5.16 lists the results from using this hybrid ARIMA/ANN model to make the forecasts.

TABLE 5.16: Results from a trading system using the forecast of categorical label “U/D” from hybrid ARIMA/ANN model.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	199	0	53	0	NaN	NaN
CAC	-84	912	52	0	50	2
FTSE	1400	151	53	2	49	0
Dow	5218	-1607	55	6	45	-10
Nikkei	234	1360	53	12	51	1
AORD	-2712	-47	52	-3	25	-12

### 5.8.2 ARIMA/k-Nearest Neighbour (k-NN)

An Arima/k-NN model was also employed in an attempt to predict the categorical label indicating whether the financial markets would move up or down. The forecasts produced from these hybrid models were also applied to the trading algorithms listed in A section A.2.4. Table 5.17 lists the results from this combination.

As the results from Table 5.17 were good, the algorithm was re-run but this time a stop loss was introduced. A stop loss of 100 points was applied to all the markets and the amended results can be seen in Table 5.18. In a similar manner as encountered

TABLE 5.17: Results from a trading system using the forecast of categorical label "U/D" from hybrid ARIMA/k-NN model.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-1515	-1714	52	-3	45	-4
CAC	-377	619	53	-1	51	1
FTSE	-266	-1515	52	-1	48	-3
Dow	3211	-3614	55	6	44	-8
Nikkei	2707	3834	50	6	52	8
AORD	-2445	220	53	-4	50	1

previously, the use of the stop loss was beneficial for all the markets except the Dow in which case it had a large detrimental affect.

TABLE 5.18: Results from a trading system with a stop loss using the forecast of categorical label "U/D" from hybrid ARIMA/k-NN model.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-444	-1122	51	-1	45	-2
CAC	-431	689	53	-1	51	1
FTSE	81	-1162	52	0	48	-2
Dow	5475	-1922	51	11	42	-4
Nikkei	4021	2804	48	9	49	6
AORD	254	245	53	0	50	1

### 5.8.3 ARIMA/Support Vector Machine (SVM)

ARIMA was also married with a SVM learner in order to predict the categorical value, "U" or "D". SVM is used in binary classification to assign data sets to one of two options, in this case "U" or "D". Given a data set labelled as belonging to one of two possible sets, a model is built that assigns new examples into one of the categories. Support vector machines operate by building a set of hyperplanes in a high dimensional space which can then be used for classification or regression. The algorithm works by choosing the hyperplanes that are furthest from the nearest data points, which intuitively would provide the best classification between two sets of data points.

Table 5.19 lists the results of passing forecasts made using this combination to the trading algorithm listed in A section A.2.4.

TABLE 5.19: Results from a trading system using the forecast of categorical label "U/D" from hybrid ARIMA/SVM model.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	-123	-322	53	0	46	-1
CAC	-140	855	54	0	50	1
FTSE	2115	866	54	5	49	1
Dow	2138	-4686	57	10	45	-6
Nikkei	9	1135	48	0	51	2
AORD	-2364	301	53	-4	49	1

## Chapter 6

# Analysis

### 6.1 Introduction

In chapters 4 and 5 a wide variety of analytical techniques were applied to a range of time series data sets. In Chapter 4 a number of trading algorithms were developed based on technical analysis indicators, with the intention of automating the decision of whether to buy or sell a market. For comparison purposes, two simple so called "naive" systems were explored to act as a baseline against which the technical analysis indicators could be compared. The technical indicators were grouped together into their general area of applicability, namely trend detection indicators, reversal, momentum and candlestick indicators.

Chapter 5 continued the exploration of financial time series through the use of exponential smoothing, ARIMA and hybrid ARIMA techniques. The generated models were used to create one-step ahead forecasts which were then added to the original data sets. These amended data sets were then fed into trading algorithms which used the forecast values to make buying decisions.

### 6.2 Technical Analysis

#### 6.2.1 Baseline Systems

Initially two simple, naive systems were explored so that they could be used as a baseline against which the developed predictive models could be compared. These systems were

the Naive Long System which mirrors a buy and hold strategy and a Naive Reversing System which simply trades in the opposite direction to the previous days market movement.

The first baseline system tried was the Naive Long system in which a market buy is placed each day and is similar to the so-called “Buy and Hold” technique. The assumption here is that the market rises over time and if an investor simply holds a security it will eventually generate a profit. The total profit is the price at the start, in this case the data set started in 2000, subtracted from the price at the end of the period, which in this case was the end of 2013.

The first iteration of the algorithm placed a buy at the start of the trading session and closed it at the end and thus the system was out of the market overnight. This resulted in significant discrepancies from the returns expected from a buy and hold system. Table 6.1 lists the expected returns from a Buy and Hold system over this period, with the Difference column being the profit or loss over the time.

TABLE 6.1: Returns from a “Buy and Hold” technique.

Date	Start 2000	End 2013	Difference	% Change
DAX	6961	9552	+2591	+37
CAC	6024	4250	-1774	-29
FTSE	6930	6749	-181	+3
Dow	11501	16576	+5075	+44
Nikkei	18937	16291	-2646	-14
AORD	3152	5353	+2201	+70

From simply trading long during market hours the DAX generated a loss as opposed to the 2591 profit expected, likewise the CAC showed a much larger loss than expected and the Nikkei resulted in a large loss when a small loss was expected. The Dow, FTSE and AORD were similar to the expected values. The discrepancies in the returns between the trading algorithm and a Buy and Hold approach was due to the fact that the algorithm opened and closed trades each day as opposed to simply opening the trade and waiting several years. This first algorithm was simply trading within market hours, approximately 8am to 5pm local time, and was not in the market for the full 24 hours of the day.

Changing the algorithm such that the trades ran from the market close time until the close time of the following day and thus covered the full 24 hour period resulted in system results that matched those expected from a buy and hold approach. Clearly the discrepancies from the first algorithm were due to the relative amounts the markets moved during the day as opposed to during the “out of hours” trading. There is a slight



bias for the markets to move upwards overnight and over the course of the study (14 years) adds up to significant values.

The second naive system was termed the “Naive Reversing” system and simply places a trade today in the opposite direction from the previous day. This idea produced reasonable returns, with every market making money. From these results it can be concluded that the markets have a tendency to “flip flop” and reverse back on themselves, and the phenomena of market reverses is well understood. This second concept produced far better results than the first and was thus used as the primary basis of comparison for the algorithms and systems developed from technical indicators and time series methods. For convenience the results from this system are reproduced in Table 6.2.

TABLE 6.2: Results from a naive trading system which simply trades in the opposite direction to the previous day’s movement.

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	947	3131	53	1	49	2
CAC	940	7810	53	1	53	4
FTSE	4284	4115	53	3	50	2
Dow	15799	6047	56	10	49	3
Nikkei	2324	20486	51	1	54	12
AORD	1264	237	53	1	48	0

### 6.2.2 Trend Detection

The first group of the technical analysis indicators studied were the trend detection indicators. Identification of trend direction and strength is very important in the world of financial trading and one of the most widely encountered phrases is “the trend is your friend”, as most authorities advocate trading in the direction of the trend. (In fact on a recent webinar it was claimed that 80% of all money made is made trading in the direction of the trend.) Well known indicators that purport to assist the trader in identifying trends are the simple moving average (SMA), the moving average convergence/divergence indicator (MACD) and the Aroon indicator.

The use of simple moving average is wide-spread in the financial markets. Market participants track moving averages or even more than one and make a decision which way to trade based on the position of the current price relative to it. Popular values to use in the SMA are 25, 50 and 200 for the look back period. The results of a trading system based on SMA is presented in Table 4.5 of Chapter 4. The algorithm places a buy trade if the current price is above the SMA and a sell trade if it is below it.

Results are mixed from using the SMA, with some markets producing positive results and some ending in losses. The German DAX and Australian AORD produce positive results across all the SMA values with returns from trading short (predicting the market will decline) doing best. The Japanese Nikkei and French CAC display different behaviour in that all the SMA values tried produce negative results in trying to predict long trades but positive returns when attempting to predict short trades. The UK's FTSE 100 is different again, producing negative results across the board. Finally, the Dow produces positive results for trades on the long side but losses for trading short.

In an attempt to improve the returns from the trading system a stop loss was introduced. Comparing Tables 4.5 and 4.6 of Chapter 4 it can be seen that applying the stop loss has been on the whole beneficial to the results obtained, with the exception of those from the Dow which were negatively impacted. Essentially losing trades have been truncated while winning trades have been left to develop. This general pattern of a stop loss being beneficial to all the markets except the US Dow was seen multiple times with the systems tested.

The second trend detection indicator explored was the Moving Average Convergence Divergence (MACD) indicator, full details of which can be found in section B.1 of Appendix B. The MACD can generally be used two ways, as a trend detection indicator and as an over-bought/over-sold indicator in which case traders use it to identify potential market reversals. In this section the indicator was used as a trend detector and the results from a system based on the MACD indicator can be seen in Table 4.7 in Chapter 4. The algorithm trades long when the value of MACD is greater than the value of the signal line, see Appendix A section A.1.3.2 for details of the R code used. The results are not very impressive, only the Nikkei producing reasonable profits, although they wouldn't beat the baseline Naive Reversing system.

The final trend detection indicator examined was Aroon. This indicator measures the number of intervals since the previous high or low within a certain time window. The algorithms presented here used a time window of 20 days. If the current day was the highest price in the last 20 days trading, the indicator would take a value of 100 and for each following day that doesn't make a new high the indicator falls by 5 (100 divided by the lag period which is 20). Thus if the highest price was four days ago the AroonUp value would be 80. The opposite situation occurs with regard to the low price. A value of 70 or above for the AroonUp is indicative of an upward trending market and likewise a value of 70 and above for AroonDn suggests a falling market.

The results from an algorithm using the Aroon indicator can be seen in Table 4.8 of Chapter 4. Overall the results are encouraging with the DAX, FTSE, Dow and AORD all producing positive returns for both long and short trades, while the CAC and Nikkei

are positive when trading short. Table 6.3 lists the values derived from the Aroon system with those from the baseline Reversing system (see Chapter 4 section 4.2.2) subtracted. Because the Aroon system doesn't execute trades each day it only makes sense to compare the average daily returns as opposed to the total returns. As can be seen from Table 6.3, compared with the baseline system for some markets the Aroon indicator outperforms the baseline while for others it is worse, notably the Nikkei. Considering the second column in Table 6.3, "Diff in Mean Long PL" only the DAX and AORD outperformed the baseline reversing system in producing long winning trades. Alternatively, the system based on the Aroon indicator was superior in predicting winning short trades for all the markets except the Nikkei, as seen in the third column "Diff in Mean Short PL".

TABLE 6.3: Results from baseline Reversing System subtracted from Aroon results.

Mkt	Diff in Mean Long PL	Diff in Mean Short PL
DAX	2	2
CAC	-2	0
FTSE	-1	3
Dow	-3	0
Nikkei	-4	-2
AORD	1	3

The trading system based on the Aroon indicator was re-run with a stop loss value of 100. Overall the use of a stop loss improves the returns, with the exception of the Dow. One again using a stop loss with the Dow shows very marked negative impacts on profits. These results can be seen in 4.9 of Chapter 4.

### 6.2.3 Market Reversal Indicators

In this section two indicators that purport to assist in identifying market reversals are examined, namely the Parabolic Stop-and-Reverse (SAR) and the Moving Average Convergence Divergence (MACD) used as an over-bought/over-sold indicator.

The first market reversal indicator explored was the Parabolic Stop-and-Reverse (SAR), an indicator initially developed for traders who were always in the market with either long or short position. The SAR is used to judge when the position should be reversed from long to short or vice versa. The trading algorithm reported here trades each day (i.e opens a trade at the start of the trading session and closes it out at the end) and makes a decision regarding the direction of the trade based on the SAR indicator. If the market opening is above the SAR a long trade is initiated and vice versa if the market is below the SAR value.

The results from the trading system based on the SAR can be seen in Table 4.11 of Chapter 4 and are very poor. Only the Nikkei trading short produces reasonable results, but these are much worse than the baseline Naive Reversing method introduced previously.

As previously mentioned the MACD indicator can be used as a market reversal indicator. Once the MACD value reaches its extreme values, the market is considered over-bought or over-sold and likely to reverse back on itself. The trading algorithm using this concept expects a market reversal once the MACD crosses above the 85% quantile (of the MACD range) or below the 15% quantile. Short trades are initiated once the MACD crosses above the 85% quantile value and short trades once it has passed below the 15% quantile. The results from this trading system can be seen in Table 4.12 and are very unimpressive being inferior to the baseline method.

Both market reversal indicators resulted in poor results. However, the trading horizon was short at just one day. Given the difficult task at hand, trying to pin point the reversal of a financial market perhaps a longer trading horizon may have helped. This might have allowed leeway in the timing and caught any reversals that may have occurred two or three days later. This is an area for future research.

#### 6.2.4 Momentum Indicators

A third category of technical indicators are the momentum indicators, which are related to the trend detection indicators (Menkhoff et al., 2012). Two such indicators are studied here, the stochastic and the rate of change (ROC). The stochastic oscillator is one of the oldest and most widely used of the technical indicators. It measures the percentage position the current close is in relation to the high low range of the period of interest. For example the current close could be 80% of the way between the low and high of the last 10 days. Thus it has conceptual similarities to the Aroon indicator. The stochastic is usually represented by two lines %K which is the position of the price within this high low envelope described above, and %D a moving average of %K (see Appendix B section B.4 for more details).

The trading algorithm utilising the stochastic initiates long trades when %K is above %D and short trades when %K is below %D. Results from an algorithm implementing these ideas can be seen in Table 4.13 in Chapter 4. The results of this system are poor being significantly worse than the baseline Naive Reversing system.

The second momentum indicator is the Rate Of Change (ROC) indicator, and this is simply the difference between the current price and a price a certain number of days

previously. If this value is positive the market is considered to be trending up and the larger the value the greater the trending momentum. The results from an algorithm using these ideas is presented in Table 4.13 of Chapter 4. The results are positive but very modest and inferior to the baseline Reversing system.

### 6.2.5 Breakout systems

The fourth area of technical analysis explored the idea of trade signals being generated by a particular value from the previous day, so-called breakout systems. Two particular values are used as the trigger price for a trade, the previous day's high/low or the 90% quantile of the minor move (see section 3.2.5 of Chapter 3).

The first idea explored was to use the previous time period's high or low price as a trigger for a buy or sell. If the current day's high price exceeded the previous day's high price a long trade would be made and in a similar manner if today's low price is lower than previous day's low a short trade is initiated. Results from using the previous day's high price or low price as a trigger to trade long or short can be seen in Table 4.16. Generally the results are very good with the exception of the Dow. These results can be linked to the data exploratory work shown in Table 3.6 of section 3.2.3. The best returns were generated in the Nikkei, a market which had the highest number of times closing outside the previous day's high or low. Conversely, the lowest ranked market in terms of closing outside yesterday's high low range was the Dow, and this was the one market that produced negative results in the break-out system. Table 6.4 lists the returns from the high low breakout system with the profits from the baseline Naive Reversing system subtracted. As can be seen, with the exception of the Dow, the method out-performs the baseline system markedly.

TABLE 6.4: Results from Daily High / Low Breakout System compared with Naive Reversing System

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	11278	10280	2	6	5	6
CAC	2551	-855	0	1	0	0
FTSE	8905	14366	6	4	9	10
Dow	-35397	-34384	-14	-21	-11	-20
Nikkei	29664	23068	6	18	4	15
AORD	15961	18947	13	9	17	13

The second break-out system used the minor fluctuation 90% quantile value as the trigger level to trade long or short. Once the market moved above this level a long trade was made or if the market moved below this level a short trade was executed. Overall this methodology produces good results with the exception of the Dow and CAC. Table 6.5

lists the difference in results between this breakout methodology and the baseline Naive Reversing system.

TABLE 6.5: Results 90% Quantile level Breakout System compared with Naive Reversing System

Mkt	LongPL	ShortPL	L Win %	Av L PL	S Win %	Av S PL
DAX	6894	3240	3	5	4	2
CAC	1707	-2725	1	1	-1	-1
FTSE	6474	11180	3	4	4	8
Dow	-46061	-40901	-17	-34	-12	-31
Nikkei	21282	11344	7	15	2	8
AORD	15466	19120	10	8	14	12

### 6.2.6 Candlestick Patterns

A number of so-called candlestick patterns were explored for predictive properties in financial markets. The patterns tested were essentially market reversal patterns. Firstly, Hammer and Inverted Hammer were considered. When these patterns occur it is considered a sign that the market will move upwards, especially when they are encountered in a down trend, thus reversing direction. Table 4.18 lists the results from placing buy trades after all occurrences of either pattern while Table 4.19 shows the results from initiating buy trades when these patterns occur in trending markets. The Aroon indicator detailed in section B.2 of Appendix B was used to determine if the market was in a trending phase. Overall the results from using the Hammer or Inverted Hammer candlestick pattern to predict market movement was poor. Only the Dow and FTSE showed positive results, although the per trade profit from the Dow was good. Another consideration is the small number of times in which these patterns occur, only 22 trades in the 14 years of the Dow data were made. Clearly these visual patterns are quite subjective and in reality a trader would use judgement as to whether the pattern constituted a Hammer or not. However, in developing an algorithm to recognise and trade them no such latitude is possible and thus the number of trades taken by the algorithms is likely to be less than in reality.

The next pattern tested was the Engulfing pattern. This pattern occurs when a candlestick has a lower low and a higher high than the previous day's candlestick, it engulfs it. The presence of this pattern is supposed to indicate that the market will change direction. The results of a trading algorithm that trades long or short depending upon the presence of an Engulfing candlestick can be seen in Table 4.20. The results shown in Table 4.21 are similar to Table 4.20 except trades are only taken if the market is trending, with the Aroon indicator used to determine if the market is in a trending phase.

The results from both algorithms were very poor, with most markets showing negative results.

The final pattern tested was the Doji, one of the best known candlestick patterns. Again the presence of this pattern in a trending market is supposed to give warning to the market participants that a reversal may be imminent. Table 4.22 shows the results of a trading system that uses the presence of a Doji in a trending market to initiate a trade. Again the results are very poor with mostly negative returns.

None of the candlestick patterns produced good results in the trading algorithms and time frames used. Given the subjective nature of what constitutes the particular pattern and the context in which it occurs it is difficult to generate trading systems through computer programming. Further, it may be beneficial to alter the trading time frame to a longer period and perhaps combine these patterns with additional technical analysis indicators, and is an area suitable for further work.

## 6.3 Time Series Analysis

Exponential smoothing, ARIMA and hybrid ARIMA models were used to generate forecasts of the closing prices and the more general situation of whether the market would rise or fall. In modelling the more general situation of market direction, a categorical label was employed. The categorical label used “U” to represent occasions when the market prices increased and “D” for when it decreased in value.

### 6.3.1 Exponential Smoothing

Exponential smoothing was used to make one-step ahead forecasts for the indice data sets. Initially two base systems were explored in order that they could be used as a baseline against which later results could be compared. The two methods generated predictions using a mean method in which the forecast was simply the average of the sample and a drift method which is the extrapolation of a straight line between the first and last point in a data sample. For all the forecasts generated in this section a moving window approach was adopted. A window of sample data points was used, typically the last 30 observations, for which a forecast was generated using one of the methods. This window was then advanced one observation forward and the forecast for this data set calculated and the process repeated for the entire data set.

Once the forecasts were generated they were passed to a trading algorithm which made decisions regarding whether to trade long or short based on the value of the forecast. If

the forecast was higher than the previous closing price a long trade was initiated or if it was lower a short trade was made with the expectation that the market would fall. Results from the forecasts generated from the mean method can be seen in Table 5.2 while results from the drift method can be seen in Table 5.3. Both systems produced poor results and wouldn't generate enough profits to offset any transaction costs that would be incurred in the real world.

Next exponential smoothing was used to generate forecasts. Allowing for trend, seasonality and whether there are additive or multiplicative affects, a variety of models may be used to generate predictions. The `ets()` function of the forecast package in R can create models from all the available possibilities. Once again using a moving window approach, one-step ahead forecasts were created for the indice data sets. As the window moved through the data, different models were selected as being the best fit and these used to generate the forecasts. Having generated the predictions they were passed to the same trading algorithm as used for the mean and drift models, and the results can be seen in Table 5.5.

On the whole the results from the models generated from exponential smoothing are quite poor, with only the Dow producing reasonable, though very modest results. In comparison to the base systems developed from mean and drift methods, the adaptive exponential smoothing concept produces higher profits in general when all the results are considered, but there are much better results when other time series techniques or technical analysis methods are considered.

### 6.3.2 ARIMA Models

The `auto.arima()` function of the R forecast package was used to assist in generating ARIMA models for the national indice data sets used in this study. For convenience the models selected are listed in Table 6.6.

TABLE 6.6: Arima models chosen to forecast future values in the national indice data sets.

Market	Arima Model
DAX	ARIMA(3,1,3)
CAC	ARIMA(2,1,3)
FTSE	ARIMA(2,1,3)
Dow	ARIMA(1,1,2)
Nikkei	ARIMA(2,1,3)
AORD	ARIMA(1,1,0)



The one-step forecasts generated from these models were then used in two trading systems. In the first algorithm the decision to trade long or short was dependant upon on the relative values of the previous close price and the forecast. If the forecast was higher than the close price a long trade was entered in the expectation that the market would rise towards the prediction. The opposite situation was expected for when the forecast was lower than the close price. The R code for this first algorithm can be seen in Appendix A section A.2.2 and is labelled system 1.

The second trading algorithm used the relative values of the predictions themselves in order to decide whether to trade long or short. If the current forecast was higher than the previous one a long trade was made and vice versa. The R code for this second algorithm can be seen in Appendix A section A.2.3 and is labelled system 2.

The results from both systems were poor. The difference in mean PL per trade between the first system based on the auto.arima models (previous close in comparison to forecast) and the mean PL for the Naive Reversing system from section 4.2.2 Chapter 4 can be seen in Table 6.7. Most of the results are worse than the naive baseline system except for the French CAC and US Dow when trading long.

TABLE 6.7: Mean Long/Short PL from system using predictions from ARIMA models with the results from the Naive Reverse system subtracted.

Mkt	Diff in Mean Long PL	Diff in Mean Short PL
DAX	-6	-11
CAC	2	-3
FTSE	1	-3
Dow	-3	-14
Nikkei	20	1
AORD	1	-1

### 6.3.3 ARIMA Hybrids - Predicting Closing Price

Hybrid ARIMA models in which Artificial Neural Networks and k-Nearest Neighbour algorithms were used instead of regression in the ARIMA algorithm were used to predict the closing prices of financial markets, see Chapter 5 section 5.6 for details.

#### 6.3.3.1 ARIMA/Artificial Neural Networks (ANN)

Overall the use of the forecasts from the models generated from hybrid ARIMA/ANN algorithms to create trading systems was not very successful. The results from passing the indice data sets augmented with a forecast attribute generated by the hybrid ARIMA

models can be seen in Tables 5.12 and 5.13 of Chapter 5. System 1 compares the price of the forecast with the price of the previous close and in the event that the prediction is higher than the previous closing price a long trade is entered. The opposite is true when the forecast is lower than the closing price and a short trade is made. System 2 is similar but compares the forecast with the last forecast. In the event that the current prediction is greater than the previous one a long trade is initiated.

Considering the results in Tables 5.12 and 5.13 it can be seen that System 1 outperforms System 2 quite markedly. Even so, the results are quite modest across most of the indices and especially poor for the DAX. The results prove inferior to the baseline Naive Reversing System introduced in 4.2.2 Chapter 4 as shown in Table 6.8.

TABLE 6.8: Results from a trading system based on forecasts of closing price generated by the Arima/ANN model compared to baseline Naive Reversing methodology.

Mkt	Diff in Mean Long PL	Diff in Mean Short PL
DAX	-2	-4
CAC	1	-2
FTSE	-2	-4
Dow	-5	-12
Nikkei	1	-8
AORD	-6	-1

### 6.3.3.2 ARIMA/k-Nearest Neighbour (k-NN)

An alternative to the ARIMA/ANN methodology is to replace ANN with a k-Nearest Neighbour learner, that looks for neighbouring data points that are similar or close (usually defined by some measure distance) to it. Results from using the forecasts generated in the two trading systems introduced in section 5.5 can be seen in Tables 5.14 and 5.15.

The results from System 1 are similar to those from the hybrid ARIMA/ANN of the previous section. In comparison to the baseline Naive Reversing approach they are likewise inferior, although for trading long they produce similar winning percentages. Table 6.9 lists the difference in results between those generated with System 1 and the ARIMA/k-NN models and the baseline system.

### 6.3.4 ARIMA Hybrids - Predicting Up Down with Categorical Label

An alternative to forecasting the closing price of a financial market is to predict the general direction it will move in the short term either up or down. To this end an

TABLE 6.9: Results from a system using forecasts from a Arima/k-NN model with the results of the Naive Reversing System subtracted.

Mkt	L Win %	Av L PL	S Win %	Av S PL
DAX	-1	-1	-4	-2
CAC	-1	-2	-3	-3
FTSE	1	-2	0	-3
Dow	1	1	-3	-7
Nikkei	-3	-1	-4	-10
AORD	0	0	2	7

additional categorical label to indicate whether the market increased or fell in value over the course of the day was introduced into the data sets. This new attribute had the value “U” if the market increased and “D” if it decreased. Hybrid ARIMA models were then employed to predict this label.

#### 6.3.4.1 ARIMA/Artificial Neural Networks (ANN)

The first methodology employed was to combine ARIMA with Artificial Neural Networks (ANN) in order to generate a forecast of the categorical label that indicated whether the market increased in value or fell over the course of the day. Once the forecast was generated and added to the data set in the form of a new attribute it was passed to a trading algorithm which based the decision whether to trade long or short on the forecast generated. The R code for the trading algorithm can be seen in Appendix A section A.2.4 and the results generated in Table 5.16. Overall the results were poor and inferior to the baseline system used for comparison.

#### 6.3.4.2 ARIMA/k-Nearest Neighbour (k-NN)

Replacing the ANN learner from the previous section with a k-NN method resulted in similar results. Again the returns from using the hybrid methodology was inferior to the baseline methodology. Table 5.17 lists the results of passing the forecasts from this combination to the trading algorithm in Appendix A section A.2.4. Table 6.10 lists the difference in results between using this hybrid ARIMA approach and the usual baseline returns.

#### 6.3.4.3 ARIMA/Support Vector Machine (SVM)

Finally, the ARIMA methodology was coupled with a Support Vector Machine (SVM) learner. The SVM is appropriate here because the categorical label being forecast is

TABLE 6.10: Results from Naive Reversing System subtracted from results generated from predicting Up/Down categorical label using Arima/k-NN.

Mkt	L Win %	Av L PL	S Win %	Av S PL
DAX	-1	-4	-4	-6
CAC	0	-2	-2	-3
FTSE	-1	-4	-2	-5
Dow	-1	-4	-5	-11
Nikkei	-1	5	-2	-4
AORD	0	-5	2	1

binary, there are only the values "U" or "D" representing up (the market increased) and down (the market fell) respectively. The results from passing the generated forecast to the same trading algorithm as that used in the previous section and described in Appendix A section A.2.4 can be seen in Table 5.19 of Chapter 5. Overall the results were poor with the exception of the FTSE and the CAC and Nikkei trading long.

Table 6.11 lists the difference in results between using this hybrid ARIMA approach and the usual baseline returns.

TABLE 6.11: Results from Naive Reversing System subtracted from results generated from predicting Up/Down categorical label using Arima/SVM.

Mkt	L Win %	Av L PL	S Win %	Av S PL
DAX	0	-1	-3	-3
CAC	1	-1	-3	-3
FTSE	1	2	-1	-1
Dow	1	0	-4	-9
Nikkei	-3	-1	-3	-10
AORD	0	-5	1	1

## 6.4 Conclusion

This study delved into the issue of whether financial markets can be predicted with the use of technical analysis or times series modelling. To this end a wide variety of technical analysis indicators were explored along with a range of time series models. One aspect of technical analysis worth noting is that opinion is divided as to its value, with many voices in academia being critical of it (Kuang et al., 2014, Fang et al., 2014, Bajgrowicz and Scaillet, 2012). Having stated that, it is also a fact that it is widely, almost ubiquitously, used by participants of the financial markets (Taylor and Allen, 1992). The widespread use of technical analysis includes the large body of amateur traders as may be expected as well as professional. Indeed it was reported by Menkhoff

(2010) that most fund managers who were polled, educated professional in this arena, employ technical analysis.

The results from the technical analysis presented in Chapter 4 were grouped into the general area in which they purport to operate. These area were trend detection, market reversals, momentum indicators, break-out patterns and candlestick patterns. Of all the technical indicators explored in this study the break-out and trend detection methods seem to hold the most promise. This is in agreement with Brock et al. (1992) who also found merit in these techniques. The use of Moving Average Convergence/Divergence (MACD) is one area where the results of this study divert from the literature. The results from Chapter 4 section 4.3.2 are quite poor whereas Ulku and Prodan (2013) report profitable returns from using MACD to forecast national stock market indices.

Another area in which conflicting results are found is the use of candlestick patterns. Marshall et al. (2006) reported on unsuccessful studies using a range of candlestick patterns to assist in forecasting the Dow Jones Industrial Average. This is contrasted by Lu (2014) who reports on the successful use candlestick charts in finding profitable trades in the Taiwan stock market. Results from this study reflect the findings of Marshall et al. (2006), in that predictions from the candlestick patterns produced poor returns. However, an element of caution is required before dismissing the usefulness of candlestick patterns. Being visual patterns they need an element of subjectivity to be applied to their use and this is difficult to achieve in the rigid arena of computer programming.

The second area of study concentrated on established time series modelling techniques with a firmer basis in academia. This included the use of exponential smoothing, ARIMA and hybrid ARIMA techniques. The Holt-Winters method of exponential smoothing defines various aspects of a time series and applies a smoothing function to each (Winters, 1960). Thus models can be defined to account for stationary, trending or data sets with a seasonal element. Financial markets exhibit a variety of behaviour at different periods and thus one single smoothing model is not appropriate. The approach adopted in this study was to use a moving window technique. Thus as the window moved through the data set an appropriate model could be selected and applied for each subset of observations. The results generated from this exponential moving methodology were poor, barely producing returns better than a baseline approach that simply used the average of the data sample.

Another widely used time series modelling technique is Auto-Regressive Integrated Moving Average (ARIMA). ARIMA models were built for the data sets under study and the forecasts generated used in trading algorithms, see Chapter 5 section 5.5 for details. The results were poor with the systems unable to produce a profit.

One major limitation in the ARIMA model is the need for the relationship in the data to be linear. The use of hybrid ARIMA methods is an attempt to overcome this limitation, coupling ARIMA with a different learner such as Artificial Neural Networks (ANN), k-Nearest Neighbour (k-NN) or Support Vector Machines (SVM). There are many reports in the literature of good results obtained from the use of these hybrid methods. Wang et al. (2012), Khashei et al. (2009) and Zhang (2003) reported promising results from the use of ARIMA/ANN and Pai and Lin (2005) good results from ARIMA/SVM. This study showed only very modest returns from the use of ARIMA/ANN, ARIMA/k-NN or ARIMA/SVM.

#### **6.4.1 Research question revisited**

This study had the aim of answering the following question:

*“Can the use of technical indicators or time series analysis help to predict the future direction and movement of financial markets?”*

Essentially there are two elements to this question, the ability of technical analysis to aid in predicting future market movements and the usefulness of time series modelling techniques to predict market movements. Considering technical analysis first the results overall are quite poor and most techniques tried produced poor results, rarely beating the baseline system of simply trading in the opposite direction to the previous day, especially when this concept is married with a stop loss. Overall the breakout idea and the aroon indicator produced the best results from the technical analysis indicators. Of the times series modelling techniques explored the hybrid models produced the best results, although these were very modest.

#### **6.4.2 Future Work**

Restraints of time and resources restricted this study to a selection of technical analysis indicators and times series models. Further, the data selects were limited to national indices of daily data. There are a large number of other technical indicators that can be explored and many other financial markets including individual stocks, commodities such as gold and oil and a wide range of currency pairs. The techniques reported in this study were compared in isolation. In many situations traders use combinations of methods and this could form the basis of future work. Given the huge number of possible combinations careful consideration would have to be given to the selection of the techniques to use.

The time frame of the data used is another important consideration. This report used daily open, high, low and close data and used trading algorithms based around the day. Data sets in different times frames, particularly shorter ones such as minute or even tick data (the most granular of financial data) could be explored. Trading algorithms that hold trades for days or weeks could also be tried and this idea maybe particularly interesting for techniques such as candlestick patterns for which the predictive benefit may not be immediate.

# Appendix A

## R Code

### A.1 Chapter 4

The R code used to generate the results and tables in Chapter 4 is shown in listing A.1.1. This is followed by the individual files containing the algorithms used in the chapter.

#### A.1.1 Chapter 4 Results Generation

```
1 # Chapter 4
2 setwd("D:/Allan/DropBox/MSc/Dissertation/Thesis/RCode")
3
4 # libraries to include
5 library(xtable)
6 library(TTR)
7 library(candlesticks)
8
9 # files to include
10 source("../RCode//Utils.R")
11 source("../RCode//NaiveLongSystem.R")
12 source("../RCode//NaiveLongSystem2.R")
13 source("../RCode//NaiveReversePrev.R")
14 source("../RCode//SMA_sys.R")
15 source("../RCode//MACD_XO.R")
16 source("../RCode//Aroon.R")
17 source("../RCode//SAR.R")
18 source("../RCode//Stoch.R")
19 source("../RCode//ROC.R")
20 source("../RCode//MACD_OB.R")
21 source("../RCode//Bout_sys_2.R")
22 source("../RCode//Quant90_sys.R")
23 source("../RCode//Candle_Hammer.R")
24 source("../RCode//Candle_Hammer_aroon.R")
25 source("../RCode//Candle_Engulf.R")
26 source("../RCode//Candle_Engulf_aroon.R")
```



```

27 source("../RCode//Candle_Doji_aroon.R")
28
29 fil <- c("../Data/Dax_2000_d.csv",
30          "../Data/CAC_2000_d.csv",
31          "../Data/F100_2000_d.csv",
32          "../Data/Dow_2000_d.csv",
33          "../Data/N225_2000_d.csv",
34          "../Data/Oz_2000.csv")
35
36 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11)) # to hold results
37 std6 <- c(1,3,4,5,7,8,10)
38 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
39 NaiveRev <- run_NaiveReversePrev(fil, 0, nm)
40 misc_col <- 11
41
42 # -----
43 # ----- 1. Naive Long Base System -----
44
45 run_NaiveLongSystem <- function(fil, SLoss, nm){
46   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
47   for(i in 1:length(fil)){
48     Mkt <- read.csv(fil[i])
49     a <- NaiveLongSystem(Mkt, SLoss, nm[i])
50     df10 <- rbind(df10, a)
51   }
52   df.name <- names(a)
53   names(df10) <- df.name
54   df10 <- df10[-1,]
55   return(df10)
56 }
57
58 res1 <- run_NaiveLongSystem(fil,0,nm)
59 res1[misc_col] <- 'Naive Long'
60
61 # for summary results
62 total_res <- res1
63
64 # produce latex table
65 dat <- res1[,c(1,3,5,7)]
66 dig <- 2
67 cap = c('Naive Long System. A very simple system in which the algorithm assumes
68         the market will rise and enters a long trade each day.',
69         'Results from the Naive Long System')
69 lab = 'tab:nlng_results'
70 filename = '../Tables/chp_ta_naive_long.tex'
71 inclrnam=FALSE
72 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
73
74 # -----
75 # ----- Naive Long Base System -----
76 # ----- previous close and today's close -----
77
78 run_NaiveLongSystem2 <- function(fil,SLoss, nm){
79   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
80   for(i in 1:length(fil)){

```

```

81   Dax <- read.csv(fil[i])
82   a <- NaiveLongSystem2(Dax, 0, nm[i])
83   df10 <- rbind(df10, a)
84 }
85 df.name <- names(a)
86 names(df10) <- df.name
87 df10 <- df10[-1,]
88 return(df10)
89 }
90
91 res2 <- run_NaiveLongSystem2(fil,0,nm)
92 res2[misc_col] <- 'Naive Long 2'
93
94 # Add to total results
95 total_res <- rbind(total_res, res2)
96
97 # produce latex table
98 dat <- res2[,c(1,3,5,7)]
99 dig <- 2
100 cap = c('Naive Long System changed such that the trading period is the previous
        close price minus today\'s close.',
101         'Results from the Naive Long System trading close to close')
102 lab = 'tab:nlng_results_2'
103 filename = '../Tables/chp_ta_naive_long_ctoc.tex'
104 inclrnam=FALSE
105 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
106
107
108 # -----
109 # ----- Reverse Previous Baseline System -----
110 # -----
111
112 res3 <- run_NaiveReversePrev(fil, 0, nm)
113 res3[misc_col] <- 'Reverse Prev'
114
115 # Add to total results
116 total_res <- rbind(total_res, res3)
117
118 # produce latex table
119 dat <- res3[,c(1,3,4,5,7,8,10)]
120 dig <- 2
121 cap = c('Results from a naive trading system which simply trades in the opposite
        direction to the previous day\'s movement.',
122         'Results from the Naive Reversing System.')
123 lab = 'tab:n_rev_results'
124 filename = '../Tables/chp_ta_naive_reverse_prev.tex'
125 inclrnam=FALSE
126 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
127
128 # repeat latex table for Chp6 - affects numbering if re-use from Chp5
129 dat <- res3[,c(1,3,4,5,7,8,10)]
130 dig <- 2
131 cap = c('Results from a naive trading system which simply trades in the opposite
        direction to the previous day\'s movement.',
132         'Results from the Naive Reversing System.')

```

```

133 lab = 'tab:n_rev_results_chp6'
134 filename = '../Tables/chp_ta_naive_reverse_prev_chp6.tex'
135 inclrnam=FALSE
136 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
137
138 # repeat with a stop loss
139 res3a <- run_NaiveReversePrev(fil, -75, nm)
140 res3a[misc_col] <- 'Reverse Prev Stop Loss'
141
142 # Add to total results
143 total_res <- rbind(total_res, res3a)
144
145 # produce latex table
146 dat <- res3a[,std6]
147 dig <- 2
148 cap = c('Naive system which reverses the previous day\'s trade direction with
        stop loss.',
        'Naive Following System.')
149 lab = 'tab:n_rev_results_sl'
150 filename = '../Tables/chp_ta_naive_reverse_prev_sl.tex'
151 inclrnam=FALSE
152 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
153
154
155
156 # -----
157 # ----- Trend Detection Indicators -----
158
159 # ----- SMA
160 run_BaseSystem1SMA <- function(fil,SLoss,nm){
161   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
162   for(i in 1:length(fil)){
163     Dax <- read.csv(fil[i])
164     a <- BaseSystem1SMA(Dax, 5, SLoss, nm[i])
165     b <- BaseSystem1SMA(Dax, 25, SLoss, nm[i])
166     c <- BaseSystem1SMA(Dax, 50, SLoss, nm[i])
167     d <- BaseSystem1SMA(Dax, 100, SLoss, nm[i])
168     e <- BaseSystem1SMA(Dax, 200, SLoss, nm[i])
169     df10 <- rbind(df10, a, b, c, d, e)
170   }
171   df.name <- names(a)
172   names(df10) <- df.name
173   df10 <- df10[-1,]
174   return(df10)
175 }
176
177 res4 <- run_BaseSystem1SMA(fil,0,nm)
178
179 # Add to total results
180 total_res <- rbind(total_res, res4)
181
182 dat <- res4[,c(1,3,4,5,7,8,10,11)]
183 dig <- 2
184 cap = c('Results from a system based on SMA.', 'Results from a system based on SMA
        ')
185 lab = 'tab:sma_results'

```

```

186 filename = '../Tables/chp_ta_sma.tex'
187 inclrnam=FALSE
188 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
189
190 # SMA SLoss -----
191 run_BaseSystem1SMA2 <- function(fil,SLoss,nm){
192   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
193   for(i in 1:length(fil)){
194     Dax <- read.csv(fil[i])
195     h <- BaseSystem1SMA(Dax, 100, -50, nm[i])
196     hh <- BaseSystem1SMA(Dax, 100, -100, nm[i]) #don't use i !!!!!
197     df10 <- rbind(df10,h,hh)
198   }
199   df.name <- names(hh)
200   names(df10) <- df.name
201   df10 <- df10[-1,]
202   return(df10)
203 }
204
205 res5 <- run_BaseSystem1SMA2(fil,0,nm)
206
207 # Add to total results
208 total_res <- rbind(total_res, res5)
209
210 dat <- res5[,c(1,3,4,5,7,8,10,11)]
211 dig <- 2
212 cap = c('Results from a system based on SMA with stop loss.',
213         'Results from a system based on SMA with stop loss')
214 lab = 'tab:sma_results_SLoss'
215 filename = '../Tables/chp_ta_sma_sloss.tex'
216 inclrnam=FALSE
217 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
218
219 # -----
220 # ----- Moving Average Convergence/Divergence (MACD)}
221
222 run_MACD_X0 <- function(fil,SLoss,nm){
223   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
224   for(i in 1:length(fil)){
225     Mkt <- read.csv(fil[i])
226     ma <- MACD( Mkt[, "Open"], 12, 26, 9, maType="EMA" ) #calc MACD values
227     Mkt <- cbind(Mkt, ma)
228     a <- MACD_X0(Mkt, SLoss, nm[i])
229     df10 <- rbind(df10,a)
230   }
231   df.name <- names(a)
232   names(df10) <- df.name
233   df10 <- df10[-1,]
234   return(df10)
235 }
236
237 res6 <- run_MACD_X0(fil,0,nm)
238 res6[misc_col] <- 'MACD'
239
240 # Add to total results

```

```

241 total_res <- rbind(total_res, res6)
242
243 dat <- res6[,std6]
244 dig <- 2
245 cap = c('Results from a system using MACD as a trend indicator.',
246         'Results from a system using MACD as a trend indicator')
247 lab = 'tab:mac_trend_results'
248 filename = '../Tables/chp_ta_macd.tex'
249 inclrnam=FALSE
250 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
251
252
253 # -----
254 # ----- Aroon -----
255
256 run_aroon_sys <- function(fil,SLoss,nm){
257   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
258   for(i in 1:length(fil)){
259     Mkt <- read.csv(fil[i])
260     ar <- aroon(Mkt[c(3,4)], n=20)           #calc Aroon values
261     Mkt <- cbind(Mkt, ar)                   #Add Aroon values to orig
262     data set
263     a <- aroon_sys(Mkt, SLoss, nm[i])
264     df10 <- rbind(df10,a)
265   }
266   df.name <- names(a)
267   names(df10) <- df.name
268   df10 <- df10[-1,]
269   return(df10)
270 }
271
272 res7 <- run_aroon_sys(fil,0,nm)
273 res7[misc_col] <- 'Aroon'
274
275 # Add to total results
276 total_res <- rbind(total_res, res7)
277
278 dat <- res7[,std6]
279 dig <- 2
280 cap = c('Results from a system based on the Aroon indicator.',
281         'Results from a system based on the Aroon indicator')
282 lab = 'tab:aroon_results'
283 filename = '../Tables/chp_ta_aroon.tex'
284 inclrnam=FALSE
285 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
286
287 # ---- Aroon with SLoss
288 aroondfsl <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
289 for(i in 1:length(fil)){
290   Dax <- read.csv(fil[i])           #read data
291   ar <- aroon(Dax[c(3,4)], n=20)     #calc Aroon values
292   Dax <- cbind(Dax, ar)              #Add Aroon values to orig data
293   set
294   a <- aroon_sys(Dax, -100, nm[i])   #Call fnc

```

```

294   aroondfsl <- rbind(aroondfsl, a)
295 }
296 df.name <- names(a)
297 names(aroondfsl) <- df.name
298
299 res7a <- run_aaron_sys(fil,-100,nm)
300 aroondfsl <- res7a
301
302 res7a[misc_col] <- 'Aroon Stop Loss'
303
304 # Add to total results
305 total_res <- rbind(total_res, res7a)
306
307 dat <- res7a[,std6]
308 dig <- 2
309 cap = c('Results from a system based on the Aroon indicator with stop loss.',
310         'Results from a system based on the Aroon indicator with
          stop loss')
311 lab = 'tab:aaron_results_sloss'
312 filename = '../Tables/chp_ta_aaron_sloss.tex'
313 inclrnam=FALSE
314 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
315
316 # Aroon - Diffs - between Aroon and Aroon with Stop Loss
317 aroondfslddf <- as.data.frame(matrix(seq(3),nrow=1,ncol=3))
318 ln <- nrow(aroondfsl)
319 res <- 1:3
320 for(i in 1:ln){
321   res[1] <- aroondfsl[i,1]
322   res[2] <- as.numeric(res7a[i,3]) - as.numeric(res7[i,3])
323   res[3] <- as.numeric(res7a[i,4]) - as.numeric(res7[i,4])
324   aroondfslddf <- rbind(aroondfslddf,res)
325 }
326 df.name <- c("Market", "Long Difference", "Short Difference")
327 names(aroondfslddf) <- df.name
328 aroondfslddf <- aroondfslddf[-1,]
329
330 dat <- aroondfslddf[,c(1,2,3)]
331 dig <- 2
332 cap = c('Impact of using stop loss with Aroon trend indicator.',
333         'Impact of using stop loss with Aroon trend indicator')
334 lab = 'tab:aaron_results_sloss_diff'
335 filename = '../Tables/chp_ta_aaron_sloss_diff.tex'
336 inclrnam=FALSE
337 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
338
339 # Aroon compared to baseline system
340 res7_diff <- sub_df_av_pl(res7,NaiveRev)
341 #print table
342 dat <- res7_diff
343 dig <- 0
344 cap = c('Results from baseline Reversing System subtracted from Aroon results.',
345         'Aroon results minus baseline')
346 lab = 'tab:aaron_results_diff'
347 filename = '../Tables/chp_ta_aaron_diff.tex'

```

```

348 inclrnam=FALSE
349 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
350
351 # -----
352 # ----- Trend Reversal -----
353
354 # ----- SAR
355 run_sar_sys <- function(fil,SLoss,nm){
356   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
357   for(i in 1:length(fil)){
358     Mkt <- read.csv(fil[i])
359     sar <- SAR(Mkt[c(3,4)]) #HL
360     Mkt <- cbind(Mkt,sar)
361     a <- sar_sys(Mkt,SLoss, nm[i])
362     df10 <- rbind(df10,a)
363   }
364   df.name <- names(a)
365   names(df10) <- df.name
366   df10 <- df10[-1,]
367   return(df10)
368 }
369
370 res8 <- run_sar_sys(fil,0,nm)
371 res8[misc_col] <- 'SAR'
372
373 # Add to total results
374 total_res <- rbind(total_res, res8)
375
376 dat <- res8[,std6]
377 dig <- 2
378 cap = c('Results from a system based on the SAR indicator.',
379         'Results from a system based on the SAR indicator')
380 lab = 'tab:sar_results'
381 filename = '../Tables/chp_ta_sar.tex'
382 inclrnam=FALSE
383 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
384
385
386 # -----
387 # ----- MACD OB -----
388
389 run_MACD_OB <- function(fil,SLoss,nm){
390   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
391   for(i in 1:length(fil)){
392     Mkt <- read.csv(fil[i])
393     ma <- MACD( Mkt[, "Open"], 12, 26, 9, maType="EMA" ) #calc MACD values
394     Mkt <- cbind(Mkt, ma)                                #Add MACD values to orig
395                                                         data set
396     lw <- quantile(Mkt$macd, na.rm=T, probs=0.15)        #Calc low val for algo
397     up <- quantile(Mkt$macd, na.rm=T, probs=0.85)        #Calc up val for algo
398     a <- MACD_OB(Mkt, 0, nm[i], lw, up)
399     df10 <- rbind(df10,a)
400   }
401   df.name <- names(a)
402   names(df10) <- df.name

```

```

402   df10 <- df10[-1,]
403   return(df10)
404 }
405
406 res9 <- run_MACD_OB(fil,0,nm)
407 res9[misc_col] <- 'MACD Reversal'
408
409 # Add to total results
410 total_res <- rbind(total_res, res9)
411
412 dat <- res9[,std6]
413 dig <- 2
414 cap = c('Results from a trading system based on MACD being used as a trend
         reversal indicator.',
         'Results from a system based on MACD as trend reversal
         indicator')
415
416 lab = 'tab:mac_ob_results'
417 filename = '../Tables/chp_ta_macd_ob.tex'
418 inclnrnm=FALSE
419 print_xt(dat,dig,cap,lab,al,filename,inclnrnm)
420
421
422 #-----
423 # ----- Stochastic -----
424
425 ln <- nrow(df10)
426 for(i in 1:length(fil)){
427   Dax <- read.csv(fil[i])
428   st <- stoch(Dax[c(3,4,5)]) #HL
429   Dax <- cbind(Dax,st)
430   a <- stoch_sys(Dax, 0, nm[i])
431   df10 <- rbind(df10, a)
432 }
433 df10 <- df10[-c(1:ln-1),]
434
435 run_stoch_sys <- function(fil,SLoss,nm){
436   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
437   for(i in 1:length(fil)){
438     Mkt <- read.csv(fil[i])
439     st <- stoch(Mkt[c(3,4,5)]) #HL
440     Mkt <- cbind(Mkt,st)
441     a <- stoch_sys(Mkt, SLoss, nm[i])
442     df10 <- rbind(df10,a)
443   }
444   df.name <- names(a)
445   names(df10) <- df.name
446   df10 <- df10[-1,]
447   return(df10)
448 }
449
450 res10 <- run_stoch_sys(fil,0,nm)
451 res10[misc_col] <- 'Stoch'
452
453 # Add to total results
454 total_res <- rbind(total_res, res10)

```



```

455
456
457 dat <- res10[,std6]
458 dig <- 2
459 cap = c('Results from a system based on the Stochastic indicator.',
460         'Results from a system based on the Stochastic indicator')
461 lab = 'tab:stoch_results'
462 filename = '../Tables/chp_ta_stoch.tex'
463 inclrnam=FALSE
464 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
465
466 # ----- Stochastic plus Stop Loss
467 res10a <- run_stoch_sys(fil,-100,nm)
468 res10a[misc_col] <- 'Stoch Stop Loss'
469
470 # Add to total results
471 total_res <- rbind(total_res, res10a)
472
473 dat <- res10a[,std6]
474 dig <- 2
475 cap = c('Results from a system based on the Stochastic indicator with a stop
476         loss.',
477         'Results from a system based on the Stochastic indicator with a stop
478         loss')
479 lab = 'tab:stoch_results_sloss'
480 filename = '../Tables/chp_ta_stoch_sloss.tex'
481 inclrnam=FALSE
482 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
483
484 # ----- ROC -----
485
486 run_roc_sys <- function(fil,SLoss,nm){
487   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
488   for(i in 1:length(fil)){
489     Mkt <- read.csv(fil[i])
490     roc <- ROC( Mkt$Close )           #calc MACD values
491     Mkt <- cbind(Mkt, roc)           #Add MACD values to orig
492                                     data set
493     lw <- quantile(Mkt$roc, na.rm=T, probs=0.15) #Calc low val for algo
494     up <- quantile(Mkt$roc, na.rm=T, probs=0.85) #Calc up val for algo
495     a <- roc_sys(Mkt, SLoss, nm[i], lw, up)
496     df10 <- rbind(df10,a)
497   }
498   df.name <- names(a)
499   names(df10) <- df.name
500   df10 <- df10[-1,]
501   return(df10)
502 }
503
504 res11 <- run_roc_sys(fil,0,nm)
505 res11[misc_col] <- 'ROC'
506
507 # Add to total results
508 total_res <- rbind(total_res, res11)

```

```

507
508 dat <- res11[,std6]
509 dig <- 2
510 cap = c('Results from a system based on the ROC indicator.',
511         'Results from a system based on the ROC indicator')
512 lab = 'tab:mac_roc_results'
513 filename = '../Tables/chp_ta_roc.tex'
514 inclrn=FALSE
515 print_xt(dat,dig,cap,lab,al,filename,inclrn)
516
517 # -----
518 # ----- Break-out Systems -----
519
520 # ----- Daily Break Out -----
521 run_BaseSystem2Bout <- function(fil,Sloss,nm){
522   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
523   for(i in 1:length(fil)){
524     Mkt <- read.csv(fil[i])
525     a <- BaseSystem2Bout2(Mkt, Sloss, nm[i])
526     df10 <- rbind(df10,a)
527   }
528   df.name <- names(a)
529   names(df10) <- df.name
530   df10 <- df10[-1,]
531   return(df10)
532 }
533
534 res12 <- run_BaseSystem2Bout(fil,0,nm)
535 res12[misc_col] <- 'Daily Breakout'
536
537 # Add to total results
538 total_res <- rbind(total_res, res12)
539
540 dat <- res12[,std6]
541 dig <- 2
542 cap = c('Results from the Daily High / Low Breakout System.',
543         'Results from the Daily High / Low Breakout System')
544 lab = 'tab:hl_bout_sys'
545 filename = '../Tables/chp_ta_b_out.tex'
546 inclrn=FALSE
547 print_xt(dat,dig,cap,lab,al,filename,inclrn)
548
549 # comp to Naive
550 res_diff <- sub_df(res12,NaiveRev)
551
552 dat <- res_diff[,c(1,3,4,5,7,8,10)]
553 dig <- 0
554 cap <- c("Results from Daily High / Low Breakout System compared with Naive
555         Reversing System",
556         "Daily High / Low Breakout System compared with Naive Reversing System")
557 lab = 'tab:hl_bout_sys_diff'
558 filename = '../Tables/chp_ta_b_out_diff.tex'
559 inclrn=FALSE
560 print_xt(dat,dig,cap,lab,al,filename,inclrn)

```

```

561 #-----
562 # ----- 90% Quantile Break-out -----
563 run_BaseSystem3Quant902 <- function(fil,SLoss,nm){
564   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
565   for(i in 1:length(fil)){
566     Mkt <- read.csv(fil[i])
567     a <- BaseSystem3Quant902(Mkt, SLoss, nm[i])
568     df10 <- rbind(df10,a)
569   }
570   df.name <- names(a)
571   names(df10) <- df.name
572   df10 <- df10[-1,]
573   return(df10)
574 }
575
576 res14 <- run_BaseSystem3Quant902(fil,0,nm)
577 res14[misc_col] <- '90% Quantile Breakout'
578
579 # Add to total results
580 total_res <- rbind(total_res, res14)
581
582 dat <- res14[,std6]
583 dig <- 2
584 cap = c('Results from a system that breaks out from the 90\\% quantile level of
585         the day\\'s minor move.',
586         'Results from a break out system using the day\\'s the minor move')
587 lab = 'tab:q_90_results'
588 filename = '../Tables/chp_ta_90q.tex'
589 inclrnam=FALSE
590 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
591
592 # comp to Naive
593 res_diff <- sub_df(res14,NaiveRev)
594
595 dat <- res_diff[,c(1,3,4,5,7,8,10)]
596 dig <- 0
597 cap <- c("Results 90\\% Quantile level Breakout System compared with Naive
598         Reversing System",
599         "Daily 90\\% Quantile level Breakout System compared with Naive
600         Reversing System")
601 lab = 'tab:chp_ta_90q_diff'
602 filename = '../Tables/chp_ta_90q_diff.tex'
603 inclrnam=FALSE
604 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
605
606 # -----
607 # ----- Candlestick Patterns
608 # ----- Hammer Pattern
609 run_candle_hammer <- function(fil,SLoss,nm){
610   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
611   for(i in 1:length(fil)){
612     Mkt <- read.csv(fil[i],stringsAsFactors = FALSE)
613     Mkt <- Mkt[,c(1,2,3,4,5)]
614     Mkt$Date <- as.POSIXct(Mkt$Date,format='%d/%m/%Y')
615     Mkt_xts <- xts(Mkt[,c(2,3,4,5)],Mkt$Date)

```

```

613   hh <- as.data.frame(CSPHammer(Mkt_xts))
614   hi <- as.data.frame(CSPInvertedHammer(Mkt_xts))
615   Mkt <- cbind(Mkt,hh)
616   Mkt <- cbind(Mkt,hi)
617   a <- candle_hammer(Mkt,SLoss, nm[i])
618   df10 <- rbind(df10,a)
619 }
620 df.name <- names(a)
621 names(df10) <- df.name
622 df10 <- df10[-1,]
623 return(df10)
624 }
625
626 res15 <- run_candle_hammer(fil,0,nm)
627 res15[misc_col] <- 'Hammer Candlestick'
628
629 # Add to total results
630 total_res <- rbind(total_res, res15)
631
632 # latex table
633 dat <- res15[,c(1,3,5,6,7)]
634 dig <- 2
635 cap = c('Results from a system based on the Hammer and Inverted Hammer
        candlestick patterns.',
636         'Results from a system based on the Hammer and Inverted Hammer
        candlestick patterns')
637 lab = 'tab:hammer_results'
638 filename = '../Tables/chp_ta_hammer.tex'
639 inclrnam=FALSE
640 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
641
642 # plus aroon
643 run_candle_hammer_aron <- function(fil,SLoss,nm){
644   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
645   for(i in 1:length(fil)){
646     Mkt <- read.csv(fil[i],stringsAsFactors = FALSE)
647     Mkt <- Mkt[,c(1,2,3,4,5)]
648     Mkt$Date <- as.POSIXct(Mkt$Date,format='%d/%m/%Y')
649     Mkt_xts <- xts(Mkt[,c(2,3,4,5)],Mkt$Date)
650     hh <- as.data.frame(CSPHammer(Mkt_xts))
651     hi <- as.data.frame(CSPInvertedHammer(Mkt_xts))
652     Mkt <- cbind(Mkt,hh)
653     Mkt <- cbind(Mkt,hi)
654     ar <- aroon(Mkt$Close,n=20)
655     Mkt <- cbind(Mkt,ar)
656     a <- candle_hammer_aron(Mkt,SLoss, nm[i])
657     df10 <- rbind(df10,a)
658   }
659   df.name <- names(a)
660   names(df10) <- df.name
661   df10 <- df10[-1,]
662   return(df10)
663 }
664
665 res15a <- run_candle_hammer_aron(fil,0,nm)

```

```

666
667 # latex table
668 dat <- res15a[,c(1,3,5,6,7)]
669 dig <- 2
670 cap = c('Results from a system based on the Hammer and Inverted Hammer
        candlestick patterns occurring in a downtrend as defined by the aroon value.',
        ,
671         'Results from a system based on the Hammer and Inverted Hammer
        candlestick patterns occurring in a downtrend')
672 lab = 'tab:hammer_aroon_results'
673 filename = '../Tables/chp_ta_hammer_d_trend.tex'
674 inclrnam=FALSE
675 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
676
677 # -----
678 # ----- Engulfing Candlestick -----
679 run_candle_engulf <- function(fil,SLoss,nm){
680   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
681   for(i in 1:length(fil)){
682     Mkt <- read.csv(fil[i],stringsAsFactors = FALSE)
683     #create xts obj
684     Mkt$Date <- as.POSIXct(Mkt$Date,format='%d/%m/%Y')
685     Mkt_xts <- xts(Mkt[,c(2,3,4,5)],Mkt$Date)
686     en <- as.data.frame(CSPEngulfing(Mkt_xts))
687     #use data frame again
688     Mkt <- cbind(Mkt,en)
689     a <- candle_engulf(Mkt,SLoss, nm[i])
690     df10 <- rbind(df10,a)
691   }
692   df.name <- names(a)
693   names(df10) <- df.name
694   df10 <- df10[-1,]
695   return(df10)
696 }
697
698 res16 <- run_candle_engulf(fil,0,nm)
699 res16[misc_col] <- 'Engulfing Candlestick'
700
701 # Add to total results
702 total_res <- rbind(total_res, res16)
703
704 # latex table
705 dat <- res16[,std6]
706 dig <- 2
707 cap = c('Results from a system based on the Engulfing candlestick pattern.',
708         'Results from a system based on the Engulfing candlestick pattern')
709 lab = 'tab:engulf_results'
710 filename = '../Tables/chp_ta_englf.tex'
711 inclrnam=FALSE
712 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
713
714
715 # ----- Engulfing Candlestick with Aroon
716 run_candle_engulf_aroon <- function(fil,SLoss,nm){
717   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))

```

```

718   for(i in 1:length(fil)){
719     Mkt <- read.csv(fil[i],stringsAsFactors = FALSE)
720     #create xts obj
721     Mkt$Date <- as.POSIXct(Mkt$Date,format='%d/%m/%Y')
722     Mkt_xts <- xts(Mkt[,c(2,3,4,5)],Mkt$Date)
723     en <- as.data.frame(CSPEngulfing(Mkt_xts))
724     #use data frame again
725     Mkt <- cbind(Mkt,en)
726     ar <- aroon(Mkt$Close,n=20)
727     Mkt <- cbind(Mkt,ar)
728     a <- candle_engulf_aroon(Mkt,SLoss, nm[i])
729     df10 <- rbind(df10,a)
730   }
731   df.name <- names(a)
732   names(df10) <- df.name
733   df10 <- df10[-1,]
734   return(df10)
735 }
736
737 res16a <- run_candle_engulf_aroon(fil,0,nm)
738 res16a[misc_col] <- 'Engulfing Candlestick in Trend'
739
740 # Add to total results
741 total_res <- rbind(total_res, res16a)
742
743 # latex table
744 dat <- res16a[,std6]
745 dig <- 2
746 cap = c('Results from a system based on the Engulfing candlestick pattern in a
747         trending market.',
748         'Results from a system based on the Engulfing candlestick pattern in a
749         trending market')
748 lab = 'tab:engulf_aroon_results'
749 filename = '../Tables/chp_ta_englf_aroon.tex'
750 inclrnam=FALSE
751 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
752
753 # -----
754 # ----- Doji Candlestick -----
755 run_candle_doji_aroon <- function(fil,SLoss,nm){
756   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
757   for(i in 1:length(fil)){
758     Mkt <- read.csv(fil[i],stringsAsFactors = FALSE)
759     #create xts obj
760     Mkt$Date <- as.POSIXct(Mkt$Date,format='%d/%m/%Y')
761     Mkt_xts <- xts(Mkt[,c(2,3,4,5)],Mkt$Date)
762     dj <- as.data.frame(CSPDoji(Mkt_xts))
763     #back to data fram
764     Mkt <- cbind(Mkt,dj)
765     ar <- aroon(Mkt$Close,n=20)
766     Mkt <- cbind(Mkt,ar)
767     a <- candle_doji_aroon(Mkt,SLoss, nm[i])
768     df10 <- rbind(df10,a)
769   }
770   df.name <- names(a)

```

```

771   names(df10) <- df.name
772   df10 <- df10[-1,]
773   return(df10)
774 }
775
776 res17 <- run_candle_doji_aroon(fil,0,nm)
777 res17[misc_col] <- 'Doji Candlestick'
778
779 # Add to total results
780 total_res <- rbind(total_res, res17)
781
782 # latex table
783 dat <- res17[,std6]
784 dig <- 2
785 cap = c('Results from a system based on the Doji candlestick pattern in a
786         trending market.',
787         'Results from a system based on the Doji candlestick pattern in a
788         trending market')
789 lab = 'tab:doji_aroon_results'
790 filename = '../Tables/chp_ta_doji.tex'
791 inclrnam=FALSE
792 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
793
794 #-----
795 # -- Generate Summary tables for Appendic C -----
796 # 1. Dax
797 colnames(total_res)[11] <- 'Methodology'
798 Dx <- total_res[total_res$Mkt == 'Dax',]
799 Dx2 <- Dx[c(11,3,4,7,10)]
800
801 # latex table
802 dat <- Dx2
803 dig <- 2
804 cap = c('Chapter 4 Dax Results',
805         'Chapter 4 Dax Results')
806 lab = 'tab:chp6:dax_summary'
807 filename = '../Tables/chp_6_dax_summary.tex'
808 inclrnam=FALSE
809 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
810
811 # 2. CAC
812 Cc <- total_res[total_res$Mkt == 'CAC',]
813 Cc2 <- Cc[c(11,3,4,7,10)]
814
815 # latex table
816 dat <- Cc2
817 dig <- 2
818 cap = c('Chapter 4 CAC Results',
819         'Chapter 4 CAC Results')
820 lab = 'tab:chp6:cac_summary'
821 filename = '../Tables/chp_6_cac_summary.tex'
822 inclrnam=FALSE
823 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
824
825 # 3. FTSE

```

```

824 Ft <- total_res[total_res$Mkt == 'FTSE',]
825 Ft2 <- Ft[c(11,3,4,7,10)]
826
827 # latex table
828 dat <- Ft2
829 dig <- 2
830 cap = c('Chapter 4 FTSE Results',
831         'Chapter 4 FTSE Results')
832 lab = 'tab:chp6:ftse_summary'
833 filename = '../Tables/chp_6_ftse_summary.tex'
834 inclrnam=FALSE
835 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
836
837 # 4. Dow
838 Dw <- total_res[total_res$Mkt == 'Dow',]
839 Dw2 <- Dw[c(11,3,4,7,10)]
840
841 # latex table
842 dat <- Dw2
843 dig <- 2
844 cap = c('Chapter 4 Dow Results',
845         'Chapter 4 Dow Results')
846 lab = 'tab:chp6:dow_summary'
847 filename = '../Tables/chp_6_dow_summary.tex'
848 inclrnam=FALSE
849 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
850
851 # 5. Nikkei
852 Nk <- total_res[total_res$Mkt == 'Nikkei',]
853 Nk2 <- Nk[c(11,3,4,7,10)]
854
855 # latex table
856 dat <- Nk2
857 dig <- 2
858 cap = c('Chapter 4 Nikkei Results',
859         'Chapter 4 Nikkei Results')
860 lab = 'tab:chp6:nik_summary'
861 filename = '../Tables/chp_6_nik_summary.tex'
862 inclrnam=FALSE
863 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
864
865 # 6. Oz
866 Oz <- total_res[total_res$Mkt == 'AORD',]
867 Oz2 <- Oz[c(11,3,4,7,10)]
868
869 # latex table
870 dat <- Oz2
871 dig <- 2
872 cap = c('Chapter 4 AORD Results',
873         'Chapter 4 AORD Results')
874 lab = 'tab:chp6:aord_summary'
875 filename = '../Tables/chp_6_aord_summary.tex'
876 inclrnam=FALSE
877 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
878

```



```
879 # END
```

RCode/Chapter4.R

## A.1.2 Naive Systems

### A.1.2.1 Naive Long System

```
1 NaiveLongSystem <- function(Mkt, SLoss, MktName){
2   # Calculates the profit/loss from simply trading long.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   results vector.
9
10  results <- createResultsVector(MktName, SLoss)
11
12  # Buy Long
13  Mkt$Long <- Mkt$Close - Mkt$Open
14  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
15  #Adj for SLoss
16  if (SLoss < 0) {
17    Mkt$Long <- ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long)
18    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19  }
20
21  Stats <- calcStats(Mkt$Long)
22  results[5:7] <- Stats
23
24  return(results)
25 }
```

RCode/NaiveLongSystem.R

### A.1.2.2 Naive Long System trading close to close

```
1 NaiveLongSystem2 <- function(Mkt, SLoss, MktName){
2   # Calculates the profit/loss from simply trading long each day.
3   # Opening price is previous day's close price.
4   #
5   # Args:
6   #   Mkt: market data
7   #   SLoss: stop loss
8   #   MktName: name of market data
9   # Returns:
10  #   results vector.
11
12  results <- createResultsVector(MktName, SLoss)
```

```

13
14   Mkt$prevCl <- c(NA,Mkt$Close[ - length(Mkt$Close) ])
15
16   # Buy Long
17   Mkt$Long <- Mkt$Close - Mkt$prevCl
18   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19   #Adj for SLoss
20   if (SLoss < 0) {
21     Mkt$Long <- ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long)
22     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
23   }
24
25   Stats <- calcStats(Mkt$Long)
26   results[5:7] <- Stats
27
28   return(results)
29 }

```

RCode/NaiveLongSystem2.R

### A.1.2.3 Naive Reversing System

```

1 NaiveReversePrev <- function(Mkt, SLoss, MktName){
2   # Calculates the profit/loss from trading according to a naive idea of trading
   in the opposite direction to the previous day.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   results vector
9
10  results <- createResultsVector(MktName, SLoss)
11
12  Mkt$pl <- Mkt$Close - Mkt$Open
13  Mkt$prevPL <- c( NA, Mkt$pl[ - length(Mkt$pl) ] )
14
15  # Trade Long
16  Mkt$Long <- ifelse(Mkt$prevPL<0,Mkt$Close-Mkt$Open,NA)
17  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18  #Adj for SLoss
19  if (SLoss < 0) {
20    Mkt$Long <- ifelse(Mkt$prevPL<0,
21                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                      Mkt$Long)
23
24    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25  }
26
27  # Trade Short
28  Mkt$Short <- ifelse(Mkt$prevPL>0,Mkt$Open-Mkt$Close,NA)
29  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
30  #Adj for SLoss

```

```

31   if (SLoss < 0) {
32     Mkt$Short <- ifelse(Mkt$prevPL>0,
33                         ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
34                         Mkt$Short)
35     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36   }
37
38   Stats <- calcStats(Mkt$Long)
39   results[5:7] <- Stats
40
41   Stats <- calcStats(Mkt$Short)
42   results[8:10] <- Stats
43
44   return(results)
45 }

```

RCode/NaiveReversePrev.R

### A.1.3 Trend Detection Systems

#### A.1.3.1 SMA

```

1 BaseSystem1SMA <- function(Mkt, sma, SLoss, MktName){
2   # Calculates the profit/loss from trading according to SMA.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   profit/loss from trading according to SMA.
9
10  results <- createResultsVector(MktName, SLoss)
11
12  sma.value <- SMA(Mkt["Open"], sma) #create sma vector
13  Mkt <- cbind(Mkt, sma.value)       #add sma vector as new col
14
15  # Trade Long
16  Mkt$Long <- ifelse(Mkt$Open > Mkt$sma.value, Mkt$Close - Mkt$Open, NA)
17  results["LongPL"] <- round(sum(Mkt$Long, na.rm=T))
18  if (SLoss < 0) {
19    Mkt$Long <- ifelse(Mkt$Open > Mkt$sma.value,
20                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
21                      Mkt$Long)
22    results["LongPL"] <- round(sum(Mkt$Long, na.rm=T))
23  }
24
25  # Trade Short
26  Mkt$Short <- ifelse(Mkt$Open < Mkt$sma.value, Mkt$Open - Mkt$Close, NA)
27  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=T))
28  if (SLoss < 0) {
29    Mkt$Short <- ifelse(Mkt$Open < Mkt$sma.value,
30                      ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$

```

```

31         Mkt$Short)
32     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=T))
33 }
34
35 #calculate Long results
36 results[5:7] <- calcStats(Mkt$Long)
37
38 #calculate Short results
39 results[8:10] <- calcStats(Mkt$Short)
40
41 if (SLoss == 0){
42     results[11] <- paste("SMA",sma)
43 } else {
44     results[11] <- paste("SMA",sma)
45 }
46
47
48 return(results)
49 }

```

RCode/SMA\_sys.R

### A.1.3.2 MACD - trend indicator

```

1 MACD_X0 <- function(Mkt, SLoss, MktName){
2     # MACD cross-over system.
3     #
4     # Args:
5     #   Mkt: market data
6     #   SLoss: stop loss
7     #   MktName: market's name for print out
8     # Returns:
9     #   results vector.
10
11     results <- createResultsVector(MktName, SLoss)
12
13     # Trade Long
14     Mkt$Long <- ifelse(Mkt$macd>Mkt$signal,Mkt$Close-Mkt$Open,NA)
15     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
16     #Adj for SLoss
17     if (SLoss < 0) {
18         Mkt$Long <- ifelse(Mkt$macd>Mkt$signal,
19                             ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
20                             Mkt$Long)
21         results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
22     }
23
24     # Trade Short
25     Mkt$Short <- ifelse(Mkt$macd<Mkt$signal,Mkt$Open-Mkt$Close,NA)
26     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
27     #Adj for SLoss
28     if (SLoss < 0) {
29         Mkt$Short <- ifelse(Mkt$macd<Mkt$signal,

```

```

30         ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
31         Mkt$Short)
32     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
33 }
34
35 #calculate Long results
36 results[5:7] <- calcStats(Mkt$Long)
37
38 #calculate Short results
39 results[8:10] <- calcStats(Mkt$Short)
40
41 return(results)
42 }

```

RCode/MACD\_XO.R

### A.1.3.3 Aroon trend indicator

```

1 aroon_sys <- function(Mkt, SLoss, MktName){
2   # uses Aroon indicator to trigger trades
3   #
4   # Args:
5   #   Mkt:      Data to run system on
6   #   SLoss:    Stop Loss (if 0 not used)
7   #   MktName:  Name of market
8   # Returns:
9   #   results vector.
10
11   results <- createResultsVector(MktName, SLoss)
12   # Trade Long
13   Mkt$Long <- ifelse(Mkt$aroonUp >= 70, Mkt$Close-Mkt$Open, NA)
14   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
15   #Adj for SLoss
16   if (SLoss < 0) {
17     Mkt$Long <- ifelse(Mkt$aroonUp >= 70,
18                       ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
19                       Mkt$Long)
20     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
21   }
22
23   # Trade Short
24   Mkt$Short <- ifelse(Mkt$aroonDn >= 70, Mkt$Open-Mkt$Close, NA)
25   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
26   #Adj for SLoss
27   if (SLoss < 0) {
28     Mkt$Short <- ifelse(Mkt$aroonDn >= 70,
29                       ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
30                       Mkt$Short)
31     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
32   }
33
34   #calculate Long results
35   results[5:7] <- calcStats(Mkt$Long)

```

```

36
37   #calculate Short results
38   results[8:10] <- calcStats(Mkt$Short)
39
40   return(results)
41 }

```

RCode/Aroon.R

## A.1.4 Market Reversal Indicator

### A.1.4.1 SAR reversal indicator

```

1 sar_sys <- function(Mkt, SLoss, MktName){
2   # uses Parabolic SAR indicator to trigger trades
3   #
4   # Args:
5   #   Mkt:      Data
6   #   SLoss:    Stop Loss (if 0 not used)
7   #   MktName:  Name of market
8   # Returns:
9   #   results vector.
10
11   results <- createResultsVector(MktName, SLoss)
12
13   Mkt$prevsar <- c( NA, Mkt$sar[ - length(Mkt$sar) ])
14
15   # Trade Long
16   Mkt$Long <- ifelse(Mkt$Open > Mkt$prevsar, Mkt$Close-Mkt$Open, NA)
17   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18   #Adj for SLoss
19   if (SLoss < 0) {
20     Mkt$Long <- ifelse(Mkt$Open > Mkt$prevsar,
21                       ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                       Mkt$Long)
23     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
24   }
25
26   # Trade Short
27   Mkt$Short <- ifelse(Mkt$Open < Mkt$prevsar, Mkt$Open-Mkt$Close, NA)
28   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
29   if (SLoss < 0) {
30     Mkt$Short <- ifelse(Mkt$Open < Mkt$prevsar,
31                       ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
32                       Mkt$Short)
33     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
34   }
35
36   #calculate Long results
37   results[5:7] <- calcStats(Mkt$Long)
38
39   #calculate Short results

```

```

40   results[8:10] <- calcStats(Mkt$Short)
41
42   return(results)
43 }

```

RCode/SAR.R

#### A.1.4.2 MACD as Reversal Indicator

```

1 MACD_OB <- function(Mkt, SLoss, MktName, lw, up){
2   # MACD over-bought/sold system.
3   #
4   # Args:
5   #   Mkt: market data
6   #   SLoss: stop loss
7   #   MktName: market's name for print out
8   #   lw: value of MACD that signals end of bear runs and rev
9   #   up: value of MACD that signals end of bull runs and rev
10  # Returns:
11  #   results vector.
12
13  results <- createResultsVector(MktName, SLoss)
14
15  # Trade Long
16  Mkt$Long <- ifelse(Mkt$macd < lw, Mkt$Close - Mkt$Open, NA)
17  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18  #Adj for SLoss
19  if (SLoss < 0) {
20    Mkt$Long <- ifelse(Mkt$macd < lw,
21                      ifelse((Mkt$Low - Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                      Mkt$Long)
23    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
24  }
25
26  # Trade Short
27  Mkt$Short <- ifelse(Mkt$macd > up, Mkt$Open - Mkt$Close, NA)
28  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
29  if (SLoss < 0) {
30    Mkt$Short <- ifelse(Mkt$macd > up,
31                      ifelse((Mkt$Open - Mkt$High) < SLoss, SLoss, Mkt$Short),
32                      Mkt$Short)
33    results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
34  }
35
36  Stats <- calcStats(Mkt$Long)
37  results[5:7] <- Stats
38
39  Stats <- calcStats(Mkt$Short)
40  results[8:10] <- Stats
41
42  return(results)
43 }

```

## RCode/MACD\_OB.R

**A.1.4.3 Stochastic reversal indicator**

```

1 stoch_sys <- function(Mkt, SLoss, MktName){
2   # Trading system useing Stochastic Oscillator to trigger trades
3   #
4   # Args:
5   #   Mkt:      Data
6   #   SLoss:    Stop Loss (if 0 not used)
7   #   MktName:  Name of market
8   # Returns:
9   #   results vector.
10
11  results <- createResultsVector(MktName, SLoss)
12
13  Mkt$PrevfastD <- c( NA, Mkt$fastD[ - length(Mkt$fastD) ])
14  Mkt$PrevslowD <- c( NA, Mkt$slowD[ - length(Mkt$slowD) ])
15
16  # Trade Long
17  Mkt$Long <- ifelse(Mkt$PrevfastD > Mkt$PrevslowD, Mkt$Close-Mkt$Open, NA)
18  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19  #Adj for SLoss
20  if (SLoss < 0) {
21    Mkt$Long <- ifelse(Mkt$PrevfastD > Mkt$PrevslowD,
22                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
23                      Mkt$Long)
24    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25  }
26
27  # Trade Short
28  Mkt$Short <- ifelse(Mkt$PrevfastD < Mkt$PrevslowD, Mkt$Open-Mkt$Close, NA)
29  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
30  #Adj for SLoss
31  if (SLoss < 0) {
32    Mkt$Short <- ifelse(Mkt$PrevfastD < Mkt$PrevslowD,
33                      ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
34                      Mkt$Short)
35    results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36  }
37
38  Stats <- calcStats(Mkt$Long)
39  results[5:7] <- Stats
40
41  Stats <- calcStats(Mkt$Short)
42  results[8:10] <- Stats
43
44  return(results)
45 }

```

## RCode/Stoch.R



## A.1.4.4 Rate of Change(ROC)

```

1 roc_sys <- function(Mkt, SLoss, MktName, lw, up){
2   # Rate of Change (ROC) system.
3   #
4   # Args:
5   #   Mkt: market data
6   #   SLoss: stop loss
7   #   MktName: market's name for print out
8   #   lw: value of ROC for reversal up
9   #   up: value of ROC for reversal down
10  #
11  # Returns:
12  #   results vector.
13
14  results <- createResultsVector(MktName, SLoss)
15
16  Mkt$prevROC <- c( NA, Mkt$roc[ - length(Mkt$roc) ] )
17
18  # Trade Long
19  Mkt$Long <- ifelse(Mkt$prevROC < lw, Mkt$Close-Mkt$Open, NA)
20  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
21  #Adj for SLoss
22  if (SLoss < 0) {
23    Mkt$Long <- ifelse(Mkt$prevROC < lw,
24                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
25                      Mkt$Long)
26    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
27  }
28
29  # Trade Short
30  Mkt$Short <- ifelse(Mkt$prevROC > up, Mkt$Open-Mkt$Close, NA)
31  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
32  #Adj for SLoss
33  if (SLoss < 0) {
34    Mkt$Short <- ifelse(Mkt$prevROC > up,
35                      ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
36                      Mkt$Short)
37    results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
38  }
39
40  Stats <- calcStats(Mkt$Long)
41  results[5:7] <- Stats
42
43  Stats <- calcStats(Mkt$Short)
44  results[8:10] <- Stats
45
46  return(results)
47 }

```

## A.1.5 Break Out Systems

### A.1.5.1 Break Out

```

1 BaseSystem2Bout <- function(Mkt, SLoss, MktName){
2   # Trading system based on the break out of the previous day's high/low value.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   results vector.
9
10  results <- createResultsVector(MktName, SLoss)
11
12  Mkt$prevHigh <- c( NA, Mkt$High[ - length(Mkt$High) ] )
13  Mkt$prevLow <- c( NA, Mkt$Low[ - length(Mkt$Low) ] )
14
15  # Break out high
16  Mkt$Long <- ifelse(Mkt$High>Mkt$prevHigh,Mkt$Close-Mkt$prevHigh,NA)
17  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18  #Adj for SLoss
19  if (SLoss < 0) {
20    Mkt$Long <- ifelse(Mkt$High>Mkt$prevHigh,
21                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                      Mkt$Long)
23    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
24  }
25
26  # Break out low
27  Mkt$Short <- ifelse(Mkt$Low<Mkt$prevLow,Mkt$prevLow-Mkt$Close,NA)
28  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
29  if (SLoss < 0) {
30    Mkt$Short <- ifelse(Mkt$Low<Mkt$prevLow,
31                      ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
32                      Mkt$Short)
33    results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
34  }
35
36  Stats <- calcStats(Mkt$Long)
37  results[5:7] <- Stats
38
39  Stats <- calcStats(Mkt$Short)
40  results[8:10] <- Stats
41
42  return(results)
43 }

```

RCode/Bout\_sys.R

### A.1.5.2 90% Quantile

```

1 BaseSystem3Quant902 <- function(Mkt, SLoss, MktName){
2   # Calculates the profit/loss from trading a breakout of a 90% quantile move.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   results vector.
9
10  results <- createResultsVector(MktName, SLoss)
11
12  Mkt$OH <- Mkt$High - Mkt$Open
13  Mkt$OL <- Mkt$Open - Mkt$Low
14  Mkt$mn <- ifelse(Mkt$OH>Mkt$OL,Mkt$OL,Mkt$OH)
15  qq <- quantile(Mkt$mn, probs=0.90)
16
17  # Trade Long
18  Mkt$Long <- ifelse((Mkt$High - Mkt$Open) > qq, Mkt$Close - (Mkt$Open + qq), NA)
19  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
20  #Adj for SLoss
21  if (SLoss < 0) {
22    Mkt$Long <- ifelse((Mkt$High - Mkt$Open) > qq,
23                      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
24                      Mkt$Long)
25    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
26  }
27
28  # Trade Short
29  Mkt$Short <- ifelse((Mkt$Open - Mkt$Low) > qq, (Mkt$Open - qq) - Mkt$Close, NA)
30  results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
31  #Adj for SLoss
32  if (SLoss < 0){
33    Mkt$Short <- ifelse((Mkt$Open - Mkt$Low) > qq,
34                      ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
35                      Mkt$Short)
36    results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
37  }
38
39  Stats <- calcStats(Mkt$Long)
40  results[5:7] <- Stats
41
42  Stats <- calcStats(Mkt$Short)
43  results[8:10] <- Stats
44
45  return(results)
46 }

```

## A.1.6 Candlestick Systems

### A.1.6.1 Hammer and Inverted Hammer Candlestick Pattern

```

1 candle_hammer <- function(Mkt, SLoss, MktName){
2   # Trading system based on the Hammer candlestick pattern.
3   #
4   #   Mkt: market data
5   #   SLoss: stop loss
6   #   MktName: market's name for print out
7   # Returns:
8   #   results vector.
9
10  results <- createResultsVector(MktName, SLoss)
11
12  Mkt$prev_Hammer <- c( NA, Mkt$Hammer[ - length(Mkt$Hammer) ] )
13  Mkt$prev_Inv_Hammer <- c( NA, Mkt$InvertedHammer[ - length(Mkt$InvertedHammer
14    ) ] )
15
16  # Trade Long
17  Mkt$Long <- ifelse(Mkt$prev_Hammer==TRUE | Mkt$prev_Inv_Hammer==TRUE, Mkt$Close
18    -Mkt$Open, NA)
19  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
20  #Adj for SLoss
21  if (SLoss < 0) {
22    Mkt$Long <- ifelse((Mkt$prev_Hammer==TRUE | Mkt$prev_Inv_Hammer==TRUE) > 0,
23      ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
24      Mkt$Long)
25    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
26  }
27
28  Stats <- calcStats(Mkt$Long)
29  results[5:7] <- Stats
30
31  return(results)
32 }
```

RCode/Candle\_Hammer.R

### A.1.6.2 Hammer and Inverted Hammer Candlestick Pattern in a Trending Market

```

1 candle_hammer_aroon <- function(Mkt, SLoss, MktName){
2   # Trading system based on the Hammer candlestick pattern occurring in a
3   # trending market.
4   #
5   #   Mkt: market data
6   #   SLoss: stop loss
7   #   MktName: market's name for print out
8   # Returns:
9   #   results vector.
10
11 }
```

```

10 results <- createResultsVector(MktName, SLoss)
11
12 #browser()
13 Mkt$prev_Aroon_UP <- c( NA, Mkt$aroonUp[ - length(Mkt$aroonUp) ] )
14 Mkt$prev_Aroon_DN <- c( NA, Mkt$aroonDn[ - length(Mkt$aroonDn) ] )
15 Mkt$prev_Hammer <- c( NA, Mkt$Hammer[ - length(Mkt$Hammer) ] )
16 Mkt$prev_Inv_Hammer <- c( NA, Mkt$InvertedHammer[ - length(Mkt$InvertedHammer
    ) ] )
17
18 # Trade Long
19 Mkt$Long <- ifelse(Mkt$prev_Aroon_DN >= 70, ifelse(Mkt$prev_Hammer==T | Mkt$
    prev_Inv_Hammer==T, Mkt$Close-Mkt$Open, NA) ,NA)
20
21 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
22
23 #Adj for SLoss
24 if (SLoss < 0) {
25     Mkt$Long <- ifelse((Mkt$High - Mkt$Open) > 0,
26                         ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
27                         Mkt$Long)
28     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
29 }
30
31 Stats <- calcStats(Mkt$Long)
32 results[5:7] <- Stats
33
34 return(results)
35 }

```

RCode/Candle\_Hammer\_aroon.R

### A.1.6.3 Engulfing Candlestick Pattern

```

1 candle_engulf <- function(Mkt, SLoss, MktName){
2     # Trading system based on the Engulfing candlestick pattern.
3     #
4     # Mkt: market data
5     # SLoss: stop loss
6     # MktName: market's name for print out
7     # Returns:
8     # results vector.
9
10    results <- createResultsVector(MktName, SLoss)
11
12    Mkt$prev_Bull_Engulf <- c( NA, Mkt$Bull.Engulfing[ - length(Mkt$Bull.Engulfing)
        ] )
13    Mkt$prev_Bear_Engulf <- c( NA, Mkt$Bear.Engulfing[ - length(Mkt$Bear.Engulfing)
        ] )
14
15    # Trade Long
16    Mkt$Long <- ifelse(Mkt$prev_Bull_Engulf==TRUE, Mkt$Close-Mkt$Open, NA)
17    results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18 #     #Adj for SLoss

```

```

19   if (SLoss < 0) {
20     Mkt$Long <- ifelse(Mkt$prev_Bull_Engulf == TRUE,
21                       ifelse( (Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                       Mkt$Long)
23     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
24   }
25
26   # Trade Short
27   Mkt$Short <- ifelse(Mkt$prev_Bear_Engulf == TRUE, Mkt$Open-Mkt$Close, NA)
28   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
29   #Adj for SLoss
30   if (SLoss < 0) {
31     Mkt$Short <- ifelse(Mkt$prev_Bear_Engulf == TRUE,
32                       ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
33                       Mkt$Short)
34     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
35   }
36
37   Stats <- calcStats(Mkt$Long)
38   results[5:7] <- Stats
39
40   Stats <- calcStats(Mkt$Short)
41   results[8:10] <- Stats
42
43   return(results)
44 }

```

RCode/Candle\_Engulf.R

#### A.1.6.4 Engulfing Candlestick Pattern in a Trending Market

```

1  candle_engulf_aroon <- function(Mkt, SLoss, MktName){
2    # Trading system based on the Engulfing candlestick pattern occurring in a
3    # trending market.
4    #
5    # Mkt: market data
6    # SLoss: stop loss
7    # MktName: market's name for print out
8    # Returns:
9    # results vector.
10
11    results <- createResultsVector(MktName, SLoss)
12
13    #browser()
14    Mkt$prev_Aroon_UP <- c( NA, Mkt$aroonUp[ - length(Mkt$aroonUp) ] )
15    Mkt$prev_Aroon_DN <- c( NA, Mkt$aroonDn[ - length(Mkt$aroonDn) ] )
16    Mkt$prev_Bull_Engulf <- c( NA, Mkt$Bull.Engulfing[ - length(Mkt$Bull.
17    Engulfing) ] )
18    Mkt$prev_Bear_Engulf <- c( NA, Mkt$Bear.Engulfing[ - length(Mkt$Bear.
19    Engulfing) ] )
20
21    # Trade Long

```

```

19 Mkt$Long <- ifelse(Mkt$prev_Aroon_DN >= 70, ifelse(Mkt$prev_Bull_Engulf==T, Mkt
    $Close-Mkt$Open, NA) ,NA)
20
21 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
22
23 #Adj for SLoss
24 if (SLoss < 0) {
25     Mkt$Long <- ifelse((Mkt$High - Mkt$Open) > 0,
26                         ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
27                         Mkt$Long)
28     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
29 }
30
31 #Trade Short
32 Mkt$Short <- ifelse(Mkt$prev_Aroon_UP >= 70, ifelse(Mkt$prev_Bull_Engulf==T,
    Mkt$Close-Mkt$Open, NA) ,NA)
33 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
34 #Adj for SLoss
35 if (SLoss < 0){
36     Mkt$Short <- ifelse((Mkt$Open - Mkt$Low) > 0,
37                         ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
38                         Mkt$Short)
39     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
40 }
41
42 Stats <- calcStats(Mkt$Long)
43 results[5:7] <- Stats
44
45 Stats <- calcStats(Mkt$Short)
46 results[8:10] <- Stats
47
48 return(results)
49 }

```

RCode/Candle\_Engulf\_aroon.R

#### A.1.6.5 Doji Candlestick Pattern in a Trending Market

```

1 candle_doji_aroon <- function(Mkt, SLoss, MktName){
2     # Trading system based on the Doji candlestick pattern occurring in a trending
    market.
3     #
4     # Mkt: market data
5     # SLoss: stop loss
6     # MktName: market's name for print out
7     #
8     # Returns:
9     # results vector.
10
11     results <- createResultsVector(MktName, SLoss)
12
13     #browser()
14     Mkt$prev_Aroon_UP <- c( NA, Mkt$aroonUp[ - length(Mkt$aroonUp) ] )

```

```

15 Mkt$prev_Aroon_DN <- c( NA, Mkt$aroonDn[ - length(Mkt$aroonDn) ] )
16 Mkt$prev_Doji <- c( NA, Mkt$Doji[ - length(Mkt$Doji) ] )
17 Mkt$prev_Dragonfly <- c( NA, Mkt$DragonflyDoji[ - length(Mkt$DragonflyDoji) ]
18 )
19 Mkt$prev_Gravestone <- c( NA, Mkt$GravestoneDoji[ - length(Mkt$GravestoneDoji
20 ) ] )
21 # Trade Long
22 Mkt$Long <- ifelse(Mkt$prev_Aroon_DN >= 70, ifelse(Mkt$prev_Doji==TRUE | Mkt$
23 prev_Dragonfly == TRUE, Mkt$Close-Mkt$Open, NA) ,NA)
24 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25 #Adj for SLoss
26 if (SLoss < 0) {
27 Mkt$Long <- ifelse((Mkt$High - Mkt$Open) > 0,
28 ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
29 Mkt$Long)
30 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
31 }
32 #Trade Short
33 Mkt$Short <- ifelse(Mkt$prev_Aroon_UP >= 70, ifelse(Mkt$prev_Doji==TRUE | Mkt$
34 prev_Gravestone == TRUE, Mkt$Close-Mkt$Open, NA) ,NA)
35 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36 #Adj for SLoss
37 if (SLoss < 0){
38 Mkt$Short <- ifelse((Mkt$Open - Mkt$Low) > 0,
39 ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
40 Mkt$Short)
41 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
42 }
43 Stats <- calcStats(Mkt$Long)
44 results[5:7] <- Stats
45
46 Stats <- calcStats(Mkt$Short)
47 results[8:10] <- Stats
48
49 return(results)
50 }

```

RCode/Candle\_Doji\_aroon.R

## A.2 Chapter 5

The R code used to generate the results and tables in Chapter 5 is shown in listing A.2. This is followed by the individual files containing the algorithms used in the chapter.

```

1 # Chapter 5
2 setwd("D:/Allan/DropBox/MSc/Dissertation/Thesis/RCode")
3
4 # libraries

```



```

5 library(forecast)
6 library(xtable)
7
8 #source
9 source("../RCode/Utils.R")
10 source("../RCode/es_1.R")
11 source("../RCode/ts_1.R")
12 source("../RCode/ts_2.R")
13 source("../RCode/ts_3.R")
14 source("../RCode/ts_3a.R")
15 source("../RCode/ts_4.R")
16 source("../RCode//NaiveReversePrev.R")
17
18 fil <- c("../Data/Dax_2000_d.csv",
19         "../Data/CAC_2000_d.csv",
20         "../Data/F100_2000_d.csv",
21         "../Data/Dow_2000_d.csv",
22         "../Data/N225_2000_d.csv",
23         "../Data/Oz_2000.csv")
24 nm <- c("DAX", "CAC", "FTSE", "Dow", "Nikkei", "AORD")
25
26 # Add Naive reverse prev for comparison purposes
27 # data frame will be fed into sub_df
28
29 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
30 NaiveRev <- run_NaiveReversePrev(fil, 0, nm)
31 std6 <- c(1,3,4,5,7,8,10)
32
33 # -----
34 # ----- Base Systems
35 Mkt <- read.csv("../Data/Dax_2000_d.csv")
36 Mkt$Date[2999]
37 Mkt_ts <- ts(Mkt$Close)
38 Mkt_train <- window(Mkt_ts, end=2999.99)
39 Mkt_test <- window(Mkt_ts, start=3000)
40
41 # a.build the mean model
42 mean_model <- meanf(Mkt_train, h=5)
43 a <- accuracy(mean_model, Mkt_test) #out of sample
44 rownames(a) <- c('Mean Training Set', 'Mean Test Set')
45
46 # b. build the naive model
47 naive_model <- naive(Mkt_train, h=5)
48 b <- accuracy(naive_model, Mkt_test) #out of sample
49 rownames(b) <- c('Naive Training Set', 'Naive Test Set')
50
51 # c. build the drift model
52 drift_model <- rwf(Mkt_train,drift=TRUE,h=5)
53 c <- accuracy(drift_model, Mkt_test) #out of sample
54 rownames(c) <- c('Drift Training Set', 'Drift Test Set')
55
56 # combine results
57 d <- rbind(a,c)
58
59 # produce latex table

```

```

60 dat <- d[,c(2,3,4,5,6)]
61 dig <- 0
62 cap <- c("Error measures from mean and drift models.",
63         "Error measures from mean and drift models")
64 lab = 'tab:chp_ts:sma'
65 filename = '../Tables/chp_ts_sma.tex'
66 inclrnam=TRUE
67 print_xt(dat,dig,cap,lab,a1,filename,inclrnam)
68
69 # --- plot all three base systems on Dow
70 savepdf("chp_ts_dax1")
71 Mkt_act <- window(Mkt_ts, start=3020, end=3200)
72 plot.ts(Mkt_train,
73         main="Simple Forecasting Methods",
74         xlab="Days since 2000", ylab="DAX Closing Price",
75         xlim=c(2, 3200))
76 lines(meanf(Mkt_train, h=350) $mean, lty=2)
77 lines(rwf(Mkt_train,drift=TRUE,h=350)$mean,lty=3)
78 legend("bottomright",lty=c(2,3),
79        legend=c("Mean method","Drift method"))
80 dev.off() #savepdf end
81
82 # --- plot all three base systems on Dow PLUS actual data
83 savepdf("chp_ts_dax1_plus_act_data")
84 Mkt_act <- window(Mkt_ts, start=3020, end=3200)
85 plot.ts(Mkt_train,
86         main="Simple Forecasting Methods",
87         xlab="Days since 2000", ylab="DAX Closing Price",
88         xlim=c(2, 3200))
89 lines(meanf(Mkt_train, h=350) $mean, lty=2)
90 lines(rwf(Mkt_train,drift=TRUE,h=350)$mean,lty=3)
91 legend("bottomright",lty=c(2,3),
92        legend=c("Mean method","Drift method"))
93 lines(Mkt_act, lty=4)
94 dev.off() #savepdf end
95
96 # 1. Exp Smoothing - mean model
97 # a. build data set - window thru and add prediction
98
99 # a1 - calculates mean prediction
100 exp_mean <- function(Mkt_ts, Mkt, strt, mean_flag){
101   Mkta <- Mkt
102   cc <- Mkta[1,]
103   cc$a <- 0
104   ln <- nrow(Mkt)
105   for(i in strt:ln){
106     st <- i-30
107     Mkt_slice <- window(Mkt_ts,start=st,end=i)
108     if (mean_flag == TRUE) {
109       modf <- meanf(Mkt_slice,h=1)
110     } else {
111       modf <- rwf(Mkt_slice,drift=TRUE,h=1)
112     }
113     a <- as.numeric(modf$mean)
114     c1 <- Mkta[i,]

```

```

115     ab <- cbind(c1,a)
116     cc <- rbind(cc,ab)
117   }
118   cc <- cc[-1,]
119   return(cc)
120 }
121
122 # a2 -generates data sets with predictions
123 run_exp_mean <- function(fil,nm){
124   for(i in 1:length(fil)){
125     Mkt <- read.csv(fil[i])
126     Mkt_ts <- ts(Mkt$Close)
127     res <- exp_mean(Mkt_ts,Mkt,400,TRUE)
128     browser()
129     write.csv(res,paste('../Data/ES/',nm[i],'_es_mean.csv',sep=""),row.names=
130       FALSE)
131   }
132 }
133 # a3 - run thru data sets - takes while so need to run just once
134 # run_exp_mean(fil,nm)
135
136 # a4 - use data sets in system
137 fil_mean <- c("../Data/ES/Dax_es_mean.csv",
138               "../Data/ES/CAC_es_mean.csv",
139               "../Data/ES/FTSE_es_mean.csv",
140               "../Data/ES/Dow_es_mean.csv",
141               "../Data/ES/Nikkei_es_mean.csv",
142               "../Data/ES/AORD_es_mean.csv")
143
144 run_es_1 <- function(fil,SLoss,nm){
145   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
146   for(i in 1:length(fil)){
147     Mkt <- read.csv(fil[i])
148     a <- es_1(Mkt, SLoss, nm[i])
149     df10 <- rbind(df10,a)
150   }
151   df.name <- names(a)
152   names(df10) <- df.name
153   df10 <- df10[-1,]
154   return(df10)
155 }
156
157 res_mean <- run_es_1(fil_mean,0,nm)
158 res_mean[misc_col] <- 'Mean Method'
159
160 misc_col <- 11
161 # for summary results
162 total_res <- res_mean
163
164 dat <- res_mean[,std6]
165 dig <- 2
166 cap = c('Results from trading the predictions generated by a mean exponential
167         smoothing system.',

```

```

167         'Results from trading the predictions generated by a mean exponential
           smoothing system')
168 lab = 'tab:es_mean_sys'
169 filename = '../Tables/chp_ts_es_mean.tex'
170 inclrnam=FALSE
171 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
172
173 # -----
174 # 2 - Drift model
175 run_exp_drift <- function(fil,nm){
176   for(i in 1:length(fil)){
177     Mkt <- read.csv(fil[i])
178     Mkt_ts <- ts(Mkt$Close)
179     res <- exp_mean(Mkt_ts,Mkt,400,FALSE)
180     write.csv(res,paste('../Data/ES/',nm[i],'_es_drift.csv',sep=""),row.names=
       FALSE)
181   }
182 }
183
184 # a3 - run thru data sets - takes while so need to run just once
185 #run_exp_drift(fil,nm)
186
187 fil_drift <- c("../Data/ES/Dax_es_drift.csv",
188               "../Data/ES/CAC_es_drift.csv",
189               "../Data/ES/FTSE_es_drift.csv",
190               "../Data/ES/Dow_es_drift.csv",
191               "../Data/ES/Nikkei_es_drift.csv",
192               "../Data/ES/AORD_es_drift.csv")
193
194 res_drift <- run_es_1(fil_drift,0,nm)
195 res_drift[misc_col] <- 'Drift Method'
196
197 # Add to total results
198 total_res <- rbind(total_res, res_drift)
199
200 dat <- res_drift[,std6]
201 dig <- 2
202
203 cap = c('Results from trading the predictions generated by a drift exponential
           smoothing system.',
204         'Results from trading the predictions generated by a drift exponential
           smoothing system')
205 lab = 'tab:es_drift_sys'
206 filename = '../Tables/chp_ts_es_drift.tex'
207 inclrnam=FALSE
208 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
209
210 # 3. Exp Smoothing - ets model
211 # 3a. gen data set
212 exp_sm <- function(Mkt_ts, Mkt, strt){
213   Mkta <- Mkt
214   cc <- Mkta[1,]
215   cc$a <- 0
216   cc$b <- 0
217   ln <- nrow(Mkt)

```

```

218   for(i in strt:ln){
219     st <- i-30
220     Mkt_slice <- window(Mkt_ts,start=st,end=i)
221     modf <- ets(Mkt_slice)
222     fcastf <- forecast.ets(modf,h=1)
223     a <- as.numeric(fcastf$mean)
224     b <- modf$method
225     c1 <- Mkta[i,]
226     ab <- cbind(c1,b,a)
227     cc <- rbind(cc,ab)
228   }
229   cc <- cc[-1,]
230   return(cc)
231 }
232
233 # 3b - generates data sets with predictions
234 run_exp_sm <- function(fil,nm){
235   for(i in 1:length(fil)){
236     Mkt <- read.csv(fil[i])
237     Mkt_ts <- ts(Mkt$Close)
238     res <- exp_sm(Mkt_ts,Mkt,400)
239     browser()
240     write.csv(res,paste('../Data/ES/',nm[i],'_es.csv',sep=""),row.names=FALSE)
241   }
242 }
243
244 # loop thru data sets
245 #run_exp_sm(fil,nm)
246
247 # 3d Trade ES
248 fil_es <- c("../Data/ES/Dax_es.csv",
249             "../Data/ES/CAC_es.csv",
250             "../Data/ES/FTSE_es.csv",
251             "../Data/ES/Dow_es.csv",
252             "../Data/ES/Nikkei_es.csv",
253             "../Data/ES/AORD_es.csv")
254
255 # use prev function
256 res_es <- run_es_1(fil_es,0,nm)
257 res_es[misc_col] <- 'Exponential Smoothing'
258
259 # Add to total results
260 total_res <- rbind(total_res, res_es)
261
262 dat <- res_es[,std6]
263 dig <- 2
264 cap = c('Results from trading the predictions generated by a moving window
265         exponential smoothing system.',
266         'Results from trading the predictions generated by a moving window
267         exponential smoothing system')
268 lab = 'tab:es_sys'
269 filename = '../Tables/chp_ts_es.tex'
270 inclrnam=FALSE
271 print_xt(dat,dig,cap,lab,al,filename,inclrnam)

```

```

271 # -----
272 # 2. ARIMA -----
273 Mkt <- read.csv("../Data/F100_2000_d.csv")
274 Mkt_ts <- ts(Mkt$Close)
275 Mkt_train <- window(Mkt_ts, end=2999.99)
276 Mkt_test <- window(Mkt_ts, start=3000)
277
278 # -----
279 # 2.1. Plot the data. Identify any unusual observations.
280 savepdf("chp_ts_ftse_2000-13")
281 plot.ts(Mkt_train,
282         main="FTSE 2000 - 2013",
283         xlab="Days since 2000",
284         ylab="FTSE Closing Price",
285         xlim=c(100, 3000))
286 dev.off()
287
288 # 2.2. If necessary, transform the data (using a Box-Cox transformation)
289 #to stabilize the variance.
290
291 # 2.3. If the data are non-stationary: take first differences of the
292 #data until the data are stationary.
293 savepdf("chp_ts_ftse_2000-13_diff")
294 plot(diff(Mkt_train),
295      main="First Difference of FTSE 2000 - 2013",
296      xlab="Days since 2000",
297      ylab="FTSE Daily Price Movement",
298      xlim=c(100, 3000))
299 dev.off()
300
301 # -----
302 # 2.4. Examine the ACF/PACF: Is an AR(p) or MA(q) model appropriate?
303
304 # all 3 incl diff
305 savepdf("chp_ts_ftse_2000-13_diff_acf_tsd")
306 tsdisplay(diff(Mkt_train),main="FTSE 100 between 2000 and 2013",
307          xlab="Days since 2000",
308          ylab="FTSE Daily Price Movement")
309 dev.off()
310
311 # a ACF
312 savepdf("chp_ts_ftse_2000-13_diff_acf")
313 plot(Acf(diff(Mkt_train)),
314      main="ACF of FTSE 100 between 2000 and 2013",
315      ylim=c(-0.08, 0.08))
316 dev.off()
317
318 # a PACF
319 savepdf("chp_ts_ftse_2000-13_diff_pacf")
320 plot(Pacf(diff(Mkt_train)),
321      main="PACF of FTSE 100 between 2000 and 2013",
322      ylim=c(-0.08, 0.08))
323 dev.off()
324
325 # -----

```

```

326 # 2.5. Try your chosen model(s), and use the AICc to search for a better model.
327
328 mod_ar <- function(Mkt_ts, ord, nm){
329   res <- t(as.data.frame(rep(0,4)))
330   mod <- Arima(Mkt_ts, order=ord)
331   res[1,1] <- nm
332   res[1,2] <- round(mod$aic,1)
333   res[1,3] <- round(mod$aicc,1)
334   res[1,4] <- round(mod$bic,1)
335   return(res)
336 }
337
338 results <- t(as.data.frame(rep(0,4)))
339 colnames(results) <- c('Model','AIC','AICc','BIC')
340
341 r2 <- mod_ar(Mkt_train, c(3,1,1), 'Arima(3,1,1)')
342 results <- rbind(results,r2)
343 r2 <- mod_ar(Mkt_train, c(3,1,2), 'Arima(3,1,2)')
344 results <- rbind(results,r2)
345 r2 <- mod_ar(Mkt_train, c(3,1,3), 'Arima(3,1,3)')
346 results <- rbind(results,r2)
347 r2 <- mod_ar(Mkt_train, c(2,1,1), 'Arima(2,1,1)')
348 results <- rbind(results,r2)
349 r2 <- mod_ar(Mkt_train, c(2,1,2), 'Arima(2,1,2)')
350 results <- rbind(results,r2)
351 r2 <- mod_ar(Mkt_train, c(2,1,3), 'Arima(2,1,3)')
352 results <- rbind(results,r2)
353 results <- results[-1,]
354
355 # produce latex table
356 dat <- results
357 dig <- c(0,0,2,2,2)
358 cap <- c("AIC, AICc and BIC results from alternative ARIMA models.",
359         "AIC, AICc and BIC results from alternative ARIMA models")
360 lab = 'tab:chp_ts:arima_res_r'
361 filename = '../Tables/chp_ts_arima_res_r.tex'
362 inclrnam=F
363 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
364
365 # -----
366 # 2.6. Check the residuals from your chosen model by plotting the ACF of the
      residuals,
367 #and doing a portmanteau test of the residuals.
368 #If they do not look like white noise, try a modified model.
369
370 model_used_for_res <- Arima(Mkt_train, order=c(2,1,3))
371 model_name <- forecast(model_used_for_res)$method
372
373 # a mean of residual
374 residual <- model_used_for_res$residuals
375 savepdf("chp_ts_ftse_2000-13_mean_residuals")
376 plot(residual, main = paste("Residuals from model of", model_name),
377      ylab="", xlab="Day")
378 dev.off()
379

```

```

380 # b. acf of residual
381 savepdf("chp_ts_ftse_2000-13_acf_residuals")
382 Acf(residuals(model_used_for_res),
383     main= paste("ACF of Residuals of", model_name))
384 dev.off()
385
386 # d. histogram of residuals - normal distribution
387 savepdf("chp_ts_ftse_2000-13_hist_residuals")
388 hist(residual, nclass="FD", main="Histogram of residuals")
389 dev.off()
390
391 # e. portmanteau tests
392 bb <- Box.test(residuals(model_used_for_res), lag=24, fitdf=4, type="Ljung")
393 results_bc <- as.data.frame(rep(0,3))
394 results_bc[1,1] <- round(bb$p.value,4)
395 results_bc[2,1] <- round(bb$parameter)
396 results_bc[3,1] <- round(bb$statistic)
397 colnames(results_bc) <- c(forecast(model_used_for_res)$method)
398 rownames(results_bc) <- c('p-value','x-squared','df')
399 results_bc_t <- t(results_bc)
400
401 dat <- results_bc_t
402 dig <- c(0,4,0,0)
403 cap <- c("Box Ljung test of FTSE 100 ARIMA model residuals.",
404         "Box Ljung test of FTSE 100 ARIMA model residuals")
405 lab = 'tab:chp_ts:arima_res_rbox_l'
406 filename = '../Tables/chp_ts_arima_res_r_box_l.tex'
407 inclrnam=TRUE
408 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
409
410 # 2.7 Once the residuals look like white noise, calculate forecasts.
411 model_used_for_res <- Arima(Mkt_ts, order=c(2,1,3))
412 model_name <- forecast(model_used_for_res)$method
413
414 arima_man_fcast <- forecast.Arima(model_used_for_res,Mkt_test)
415 fitted.data <- as.data.frame(arima_man_fcast$fitted);
416 Mkt_test_df <- cbind(Mkt,fitted.data)
417 colnames(Mkt_test_df) <- c('Date','Open','High','Low','Close','Forecast')
418
419 # plot the results
420 dat <- tail(Mkt_test_df)
421 dig <- 0
422 cap <- c("One step ahead forecast for FTSE 100 generated from ARIMA(2,1,3) model.",
423         "",
424         "Forecast for FTSE 100 generated from the ARIMA model")
425 lab = 'tab:chp_ts:ftse_100_fcast'
426 filename = '../Tables/chp_ts_ftse_100_fcast.tex'
427 inclrnam=F
428 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
429
430 # -----
431 # 2.8 auto.arima
432 arim_mod_fnc <- function(fil,nm){
433     dfres <- dfres <- t(c('a','b'))
434     for(i in 1:length(fil)){

```



```

434     Mkt <- read.csv(fil[i])
435     Mkt_train <- ts(Mkt$Close)
436     arima_train_mod <- auto.arima(Mkt_train)
437     dfres <- rbind(dfres, c(nm[i], forecast(arima_train_mod)$method))
438   }
439   return(dfres)
440 }
441
442 fg <- arim_mod_fnc(fil, nm)
443 fg <- fg[-1,]
444 colnames(fg) <- c('Market', 'Arima Model')
445
446 # plot the results
447 dat <- fg
448 dig <- 0
449 cap <- c("Arima models chosen to forecast future values in the national indice
      data sets.",
450         "Arima models chosen for the indice data sets")
451 lab = 'tab:chp_ts_arima_models'
452 filename = '../Tables/chp_ts_arima_models.tex'
453 inclrnam=F
454 print_xt(dat, dig, cap, lab, al, filename, inclrnam)
455
456 # plot the results for Chp 6 ...
457 dat <- fg
458 dig <- 0
459 cap <- c("Arima models chosen to forecast future values in the national indice
      data sets.",
460         "Arima models chosen for the indice data sets")
461 lab = 'tab:chp_ts_arima_models_chp6'
462 filename = '../Tables/chp_ts_arima_models_chp6.tex'
463 inclrnam=F
464 print_xt(dat, dig, cap, lab, al, filename, inclrnam)
465
466 # -----
467 # 3. Trading System
468 # using the models generated from the auto.arima function
469 df10 <- as.data.frame(matrix(seq(11), nrow=1, ncol=11))
470 ts_1_fnc <- function(fil, nm, ts1){
471   for(i in 1:length(fil)){
472     Mkt <- read.csv(fil[i])
473     Mkt_ts <- ts(Mkt$Close)
474     Mkt_train <- window(Mkt_ts, end=2999.99)
475     Mkt_test <- window(Mkt_ts, start=3000)
476     arima_train_mod <- auto.arima(Mkt_train)
477     arima_fcast <- forecast.Arima(arima_train_mod, Mkt_test)
478     arima_test_mod <- Arima(Mkt_test, model = arima_train_mod) # 1 step fcast on
      future data ...
479     arima_test_fcast <- forecast(arima_test_mod)
480     fitted.data <- as.data.frame(arima_test_fcast$fitted);
481     ln <- nrow(Mkt)
482     lw <- nrow(fitted.data)
483     Mkt_test_df <- Mkt[(ln-lw+1):ln,]
484     Mkt_test_df <- cbind(Mkt_test_df, fitted.data)
485     colnames(Mkt_test_df) <- c("Date", "Open", "High", "Low", "Close", "p")

```

```

486     if(ts1 == TRUE){
487         a <- ts_1(Mkt_test_df, 0, nm[i]) # System 1
488     } else {
489         a <- ts_2(Mkt_test_df, 0, nm[i]) # System 2
490     }
491     df10 <- rbind(df10, a)
492 }
493 df.name <- names(a)
494 names(df10) <- df.name
495 df10 <- df10[-c(1),]
496 return(df10)
497 }
498
499 # run the fnc ts_1 and apply Sys 1 to the auto.arima data
500 res1 <- ts_1_fnc(fil,nm,TRUE)
501 res1[misc_col] <- 'ARIMA - System 1'
502
503 # Add to total results
504 total_res <- rbind(total_res, res1)
505
506 # produce latex table from ts_1
507 dat <- res1[,c(1,3,4,5,7,8,10)]
508 dig <- 0
509 cap <- c("Results from trading System 1 using the forecasts generated by the
510         ARIMA models.",
511         "Results from trading System 1 using the forecasts generated by the
512         ARIMA models")
513 lab = 'tab:chp_ts:arima1'
514 filename = '../Tables/chp_ts_arima1.tex'
515 inclrnam=FALSE
516 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
517
518 # compare to Naive reverse
519 diff_df1 <- sub_df_av_pl(res1,NaiveRev)
520 # produce latex table from ts_1
521 #dat <- diff[,c(1,7,10)]
522 dat <- diff_df1
523 dig <- 0
524 cap <- c("Mean Long/Short PL from system using predictions from ARIMA models with
525         the results from the Naive Reverse system subtracted.",
526         "Mean PL from ARIMA models minus mean PL from Naive Reverse system")
527 lab = 'tab:chp_ts:arima1_diff'
528 filename = '../Tables/chp_ts_arima1_diff.tex'
529 inclrnam=FALSE
530 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
531
532 # -----
533 # run the fnc ts_2
534 # apply system 2 to auto.arima data
535 res2 <- ts_1_fnc(fil,nm,FALSE) # F = ts_2
536 res2[misc_col] <- 'ARIMA - System 2'
537
538 # Add to total results
539 total_res <- rbind(total_res,res2)
540

```

```

538 # produce latex table from ts_2
539 dat <- res2[,c(1,3,4,5,7,8,10)]
540 dig <- 0
541 cap <- c("Results from trading System 2 using the forecasts generated by the
          ARIMA models.",
542         "Results from trading System 2 using the forecasts generated by the
          ARIMA models")
543 lab = 'tab:chp_ts:arima2'
544 filename = '../Tables/chp_ts_arima2.tex'
545 inclrnam=FALSE
546 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
547
548 # ----- RM Generated Files -----
549 # ----- HYBRID ARIMA SYSTEMS -----
550
551 ts_1_2_fnc_ar <- function(fil,nm,ts1){
552   for(i in 1:length(fil)){
553     #browser()
554     Mkt <- read.csv(fil[i],stringsAsFactors=F)
555     Mkt_p <- Mkt[,c(1,2,3,4,5,20)]
556     colnames(Mkt_p) <- c("Date", "Open", "High", "Low", "Close", "p")
557     if(ts1 == TRUE){
558       a <- ts_1(Mkt_p, 0, nm[i])
559     } else {
560       a <- ts_2(Mkt_p, 0, nm[i])
561     }
562     df10 <- rbind(df10, a)
563   }
564   df.name <- names(a)
565   names(df10) <- df.name
566   df10 <- df10[-c(1),]
567   return(df10)
568 }
569
570 # ----- Predicting Closing Price -----
571 # 1. ----- Arima Ann Predicting Closing Price -----
572 fil <- c("../Data/ARIMA2/Predict_Close/ar334_ann_DAX.csv",
573         "../Data/ARIMA2/Predict_Close/ar334_ann_CAC.csv",
574         "../Data/ARIMA2/Predict_Close/ar334_ann_FTSE.csv",
575         "../Data/ARIMA2/Predict_Close/ar334_ann_Dow.csv",
576         "../Data/ARIMA2/Predict_Close/ar334_ann_Nik.csv",
577         "../Data/ARIMA2/Predict_Close/ar334_ann_Oz.csv")
578
579 #nm <- c("Dax","CAC","FTSE","Dow","Nikkei","AORD")
580 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
581
582 # a. System 1
583 res3 <- ts_1_2_fnc_ar(fil,nm,TRUE)
584 res3[misc_col] <- 'ARIMA/ANN Closing Price System 1'
585
586 # Add to total results
587 total_res <- rbind(total_res, res3)
588
589 # produce latex table from ts_1
590 dat <- res3[,c(1,3,4,5,7,8,10)]

```

```

591 dig <- 0
592 cap <- c("Results from passing closing price predictions from hybrid ARIMA/ANN
        model to System 1.",
593         "Results from passing closing price predictions from hybrid ARIMA/ANN
        model to System 1")
594 lab = 'tab:chp_ts:arima_ann_sys1'
595 filename = '../Tables/chp_ts_arima_ann_sys1.tex'
596 inclrn=FALSE
597 print_xt(dat,dig,cap,lab,al,filename,inclrn)
598
599 # comp aring to Naive Prev
600 res_diff3 <- sub_df_av_pl(res3,NaiveRev)
601
602 dat <- res_diff3
603 dig <- 0
604 cap <- c("Results from a trading system based on forecasts of closing price
        generated by the Arima/ANN model compared to baseline Naive Reversing
        methodology.",
605         "Arima/ANN predictions passed to System 1 compared to Naive Reversing
        methodology")
606 lab = 'tab:chp_ts:arima_ann_sys1_diff'
607 filename = '../Tables/chp_ts_arima_ann_sys1_diff.tex'
608 inclrn=FALSE
609 print_xt(dat,dig,cap,lab,al,filename,inclrn)
610
611 # a. System 2
612 res4 <- ts_1_2_fnc_ar(fil,nm,FALSE)
613 res4[misc_col] <- 'ARIMA/ANN Closing Price System 2'
614
615 # Add to total results
616 total_res <- rbind(total_res, res4)
617
618 # produce latex table from ts_1
619 dat <- res4[,c(1,3,4,5,7,8,10)]
620 dig <- 0
621 cap <- c("Results from passing closing price predictions from hybrid ARIMA/ANN
        model to System 2.",
622         "Results from passing closing price predictions from hybrid ARIMA/ANN
        model to System 2")
623 lab = 'tab:chp_ts:arima_ann_sys2'
624 filename = '../Tables/chp_ts_arima_ann_sys2.tex'
625 inclrn=FALSE
626 print_xt(dat,dig,cap,lab,al,filename,inclrn)
627
628 # 2. ----- Arima knn Predicting Closing Price -----
629 fil <- c("../Data/ARIMA2/Predict_Close/ar334_knn_Dax.csv",
630         "../Data/ARIMA2/Predict_Close/ar334_knn_CAC.csv",
631         "../Data/ARIMA2/Predict_Close/ar334_knn_F100.csv",
632         "../Data/ARIMA2/Predict_Close/ar334_knn_Dow.csv",
633         "../Data/ARIMA2/Predict_Close/ar334_knn_Nik.csv",
634         "../Data/ARIMA2/Predict_Close/ar334_knn_Oz.csv")
635
636 # a. System 1
637 #nm <- c("Dax","CAC","FTSE","Dow","Nikkei","AORD")
638 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))

```

```

639 # a. System 1
640 res5 <- ts_1_2_fnc_ar(fil,nm,TRUE)
641 res5[misc_col] <- 'ARIMA/k-NN Closing Price System 1'
642
643 # Add to total results
644 total_res <- rbind(total_res, res5)
645
646 # produce latex table from ts_1
647 dat <- res5[,c(1,3,4,5,7,8,10)]
648 dig <- 0
649 cap <- c("Results from passing closing price predictions from hybrid ARIMA/k-NN
        model to System 1.",
650          "Results from passing closing price predictions from hybrid ARIMA/k-NN
        model to System 1")
651 lab = 'tab:chp_ts:pred_close_arma_knn_sys1'
652 filename = '../Tables/chp_ts_pred_close_arma_knn_sys1.tex'
653 inclrnam=FALSE
654 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
655
656 # comp aring to Naive Prev
657 #res_diff <- sub_df_av_pl(res,NaiveRev)
658 res_diff5 <- sub_df(res5,NaiveRev)
659
660 # produce latex table from ts_1
661 dat <- res_diff5[,c(1,5,7,8,10)]
662 dig <- 0
663 cap <- c("Results from a system using forecasts from a Arima/k-NN model with the
        results of the Naive Reversing System subtracted.",
664          "Mean PL from hybrid ARIMA/k-NN models minus mean PL from Naive Reverse
        system")
665 lab = 'tab:chp_ts:pred_close_arma_knn_sys1_diff'
666 filename = '../Tables/chp_ts_pred_close_arma_knn_sys1_diff.tex'
667 inclrnam=FALSE
668 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
669
670 # a. System 2
671 res6 <- ts_1_2_fnc_ar(fil,nm,FALSE)
672 res6[misc_col] <- 'ARIMA/k-NN Closing Price System 2'
673
674 # Add to total results
675 total_res <- rbind(total_res, res6)
676
677 # produce latex table from ts_1
678 dat <- res6[,c(1,3,4,5,7,8,10)]
679 dig <- 0
680 cap <- c("Results from passing closing price predictions from hybrid ARIMA/k-NN
        model to System 2.",
681          "Results from passing closing price predictions from hybrid ARIMA/k-NN
        model to System 2")
682 lab = 'tab:chp_ts:pred_close_arma_knn_sys2'
683 filename = '../Tables/chp_ts_pred_close_arma_knn_sys2.tex'
684 inclrnam=FALSE
685 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
686
687 # -----

```

```

688 # ----- Arima Ann Predicting Up/Dn - Categorical -----
689 # a. Categorical
690
691 # 1. ARMA / ANN (Predicting Up/Dn - Categorical)
692 fil <- c("../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_Dax.csv",
693          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_CAC.csv",
694          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_F100.csv",
695          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_Dow.csv",
696          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_N225.csv",
697          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_ann_0z.csv")
698
699 #nm <- c("Dax","CAC","FTSE","Dow","Nik","AORD")
700 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
701
702 res7 <- ts_4_fnc_ar(fil,0, nm)
703 res7[misc_col] <- 'ARIMA/ANN Up/Down'
704
705 # Add to total results
706 total_res <- rbind(total_res, res7)
707
708 # produce latex table from ts_1
709 dat <- res7[,c(1,3,4,5,7,8,10)]
710 dig <- 0
711 cap <- c("Results from a trading system using the forecast of categorical label \
712         \"U/D\" from hybrid ARIMA/ANN model.",
713         "Results from a trading system using the forecast of categorical label \
714         \"U/D\" from hybrid ARIMA/ANN model")
715 lab = 'tab:chp_ts:pUD_CAT_arima_ann_sys'
716 filename = '../Tables/chp_ts_predUpDn_CAT_arima_ann_sys.tex'
717 inclrnam=FALSE
718 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
719
720 # -----
721 # 2. ARMA / knn (Predicting Up/Dn - Categorical)
722 fil <- c("../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_Dax.csv",
723          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_CAC.csv",
724          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_F100.csv",
725          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_Dow.csv",
726          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_N225.csv",
727          "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_knn_0z.csv")
728
729 #nm <- c("Dax","CAC","FTSE","Dow","Nikkei","AORD")
730 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
731
732 res8 <- ts_4_fnc_ar(fil, 0, nm)
733 res8[misc_col] <- 'ARIMA/k-NN Up/Down'
734
735 # Add to total results
736 total_res <- rbind(total_res, res8)
737
738 # produce latex table from ts_1
739 dat <- res8[,c(1,3,4,5,7,8,10)]
740 dig <- 0
741 cap <- c("Results from a trading system using the forecast of categorical label \
742         \"U/D\" from hybrid ARIMA/k-NN model.",

```

```

740         "Results from a trading system using the forecast of categorical label \
          "U/D\" from hybrid ARIMA/k-NN model")
741 lab = 'tab:chp_ts:pUD_CAT_arima_knn_sys'
742 filename = '../Tables/chp_ts_predUpDn_CAT_arima_knn_sys.tex'
743 inclrnam=FALSE
744 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
745
746 # 2. ARMA / knn (Predicting Up/Dn - Categorical) - SLoss
747 res8a <- ts_4_fnc_ar(fil, -100, nm)
748 res8a[misc_col] <- 'ARIMA/ANN Up/Down Stop Loss'
749
750 # Add to total results
751 total_res <- rbind(total_res, res8a)
752
753 # produce latex table from ts_1
754 dat <- res8a[,c(1,3,4,5,7,8,10)]
755 dig <- 0
756 cap <- c("Results from a trading system with a stop loss using the forecast of
          categorical label \"U/D\" from hybrid ARIMA/k-NN model.",
757         "Results from a trading system with a stop loss using the forecast of
          categorical label \"U/D\" from hybrid ARIMA/k-NN model")
758 lab = 'tab:chp_ts:pUD_CAT_arima_knn_sys_SL'
759 filename = '../Tables/chp_ts_predUpDn_CAT_arima_knn_sys_SL.tex'
760 inclrnam=FALSE
761 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
762
763 # comparing to Naive Prev
764 res_diff8 <- sub_df(res8,NaiveRev)
765
766 # produce latex table from ts_1
767 dat <- res_diff8[,c(1,5,7,8,10)]
768 dig <- 0
769 cap <- c("Results from Naive Reversing System subtracted from results generated
          from predicting Up/Down categorical label using Arima/k-NN.",
770         "Naive Reversing System subtracted from Arima/k-NN predictions")
771 lab = 'tab:chp_ts:pUD_CAT_arima_knn_sys_diff'
772 filename = '../Tables/chp_ts_predUpDn_CAT_arima_knn_sys_diff.tex'
773 inclrnam=FALSE
774 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
775
776 # 4. ARMA / SVM (Predicting Up/Dn - Categorical)
777 fil <- c("../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_Dax.csv",
778         "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_CAC.csv",
779         "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_F100.csv",
780         "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_Dow.csv",
781         "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_N225.csv",
782         "../Data/ARIMA2/PredUpDn_CAT/ar_334_UD_svm_0z.csv")
783
784 #nm <- c("Dax","CAC","FTSE","Dow","Nikkei","AORD")
785 df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
786
787 res9 <- ts_4_fnc_ar(fil,0, nm)
788 res9[misc_col] <- 'ARIMA/SVM Up/Down'
789
790 # Add to total results

```

```

791 total_res <- rbind(total_res, res9)
792
793 # produce latex table from ts_1
794 dat <- res9[,c(1,3,4,5,7,8,10)]
795 dig <- 0
796 cap <- c("Results from a trading system using the forecast of categorical label \
      "U/D\" from hybrid ARIMA/SVM model.",
797      "Results from a trading system using the forecast of categorical label \
      "U/D\" from hybrid ARIMA/SVM model")
798 lab = 'tab:chp_ts:pUD_CAT_arima_svm_sys'
799 filename = '../Tables/chp_ts_predUpDn_CAT_arima_svm_sys.tex'
800 inclrnam=FALSE
801 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
802
803 # comp aring to Naive Prev
804 res_diff9 <- sub_df(res9,NaiveRev)
805
806 # produce latex table from ts_1
807 dat <- res_diff9[,c(1,5,7,8,10)]
808 dig <- 0
809 cap <- c("Results from Naive Reversing System subtracted from results generated
      from predicting Up/Down categorical label using Arima/SVM.",
810      "Naive Reversing System subtracted from Arima/SVM predictions")
811 lab = 'tab:chp_ts:pUD_CAT_arima_svm_sys_diff'
812 filename = '../Tables/chp_ts_predUpDn_CAT_arima_svm_sys_diff.tex'
813 inclrnam=FALSE
814 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
815
816 # Chp6
817 lab = 'tab:chp_ts:pUD_CAT_arima_svm_sys_ch6'
818 filename = '../Tables/chp_ts_predUpDn_CAT_arima_svm_sys_chp6.tex'
819 inclrnam=FALSE
820 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
821
822 # -----
823 # ----- Arima Ann Predicting Up/Dn - 01 -----
824 # 1. ARMA / ANN - (Predicting Up/Dn - 01)
825 # fil <- c("../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_Dax.csv",
826 #      "../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_CAC.csv",
827 #      "../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_FTSE.csv",
828 #      "../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_Dow.csv",
829 #      "../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_N225.csv",
830 #      "../Data/ARIMA/PredUpDn_01/ar_334_01_ANN_Oz.csv")
831 #
832 # #nm <- c("Dax","CAC","FTSE","Dow","Nikkei","AORD")
833 # df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
834 #
835 # res10 <- ts_3a_fnc_ar(fil, nm)
836 #
837 # # produce latex table from ts_1
838 # dat <- res10[,c(1,3,4,5,7,8,10)]
839 # dig <- 0
840 # cap <- c("Results from a trading system using the forecast of a continous label
      from a hybrid ARIMA/ANN model.",

```



```

841 #           "Results from a trading system using the forecast of a continous label
           from a hybrid ARIMA/ANN model")
842 # lab = 'tab:chp_ts:pUD_01_arima_ann_sys'
843 # filename = '../Tables/chp_ts_predUpDn_01_arima_ann_sys.tex'
844 # inclrnam=FALSE
845 # print_xt(dat,dig,cap,lab,al,filename,inclrnam)
846
847 # -- Generate Summary tables for Chp6
848 # 1. Dax
849 colnames(total_res)[11] <- 'Methodology'
850 Dx <- total_res[total_res$Mkt == 'DAX',]
851 Dx2 <- Dx[c(11,3,4,7,10)]
852
853 # latex table
854 dat <- Dx2
855 dig <- 2
856 cap = c('Chapter 5 DAX Results',
           'Chapter 5 DAX Results')
858 lab = 'tab:chp6:dax2_summary'
859 filename = '../Tables/chp_6_dax2_summary.tex'
860 inclrnam=FALSE
861 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
862
863 # 2. CAC
864 Cc <- total_res[total_res$Mkt == 'CAC',]
865 Cc2 <- Cc[c(11,3,4,7,10)]
866
867 # latex table
868 dat <- Cc2
869 dig <- 2
870 cap = c('Chapter 5 CAC Results',
           'Chapter 5 CAC Results')
872 lab = 'tab:chp6:cac2_summary'
873 filename = '../Tables/chp_6_cac2_summary.tex'
874 inclrnam=FALSE
875 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
876
877 # 3. FTSE
878 Ft <- total_res[total_res$Mkt == 'FTSE',]
879 Ft2 <- Ft[c(11,3,4,7,10)]
880
881 # latex table
882 dat <- Ft2
883 dig <- 2
884 cap = c('Chapter 5 FTSE Results',
           'Chapter 5 FTSE Results')
886 lab = 'tab:chp6:ftse2_summary'
887 filename = '../Tables/chp_6_ftse2_summary.tex'
888 inclrnam=FALSE
889 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
890
891 # 4. Dow
892 Dw <- total_res[total_res$Mkt == 'Dow',]
893 Dw2 <- Dw[c(11,3,4,7,10)]
894

```

```

895 # latex table
896 dat <- Dw2
897 dig <- 2
898 cap = c('Chapter 5 Dow Results',
899         'Chapter 5 Dow Results')
900 lab = 'tab:chp6:dow2_summary'
901 filename = '../Tables/chp_6_dow2_summary.tex'
902 inclrnam=FALSE
903 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
904
905 # 5. Nikkei
906 Nk <- total_res[total_res$Mkt == 'Nikkei',]
907 Nk2 <- Nk[c(11,3,4,7,10)]
908
909 # latex table
910 dat <- Nk2
911 dig <- 2
912 cap = c('Chapter 5 Nikkei Results',
913         'Chapter 5 Nikkei Results')
914 lab = 'tab:chp6:nik2_summary'
915 filename = '../Tables/chp_6_nik2_summary.tex'
916 inclrnam=FALSE
917 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
918
919 # 6. Oz
920 Oz <- total_res[total_res$Mkt == 'AORD',]
921 Oz2 <- Oz[c(11,3,4,7,10)]
922
923 # latex table
924 dat <- Oz2
925 dig <- 2
926 cap = c('Chapter 5 AORD Results',
927         'Chapter 5 AORD Results')
928 lab = 'tab:chp6:aord2_summary'
929 filename = '../Tables/chp_6_aord2_summary.tex'
930 inclrnam=FALSE
931 print_xt(dat,dig,cap,lab,al,filename,inclrnam)
932
933 # END

```

RCode/Chapter5.R

### A.2.1 Exponential Smoothing

```

1 es_1 <- function(Mkt, SLoss, MktName){
2   # Trading system using predictions from exponential smoothing models.
3   #
4   #
5   # Mkt: market data
6   # SLoss: stop loss
7   # MktName: market's name for print out
8   # Returns:
9   # results vector.

```

```

10
11 results <- createResultsVector(MktName, SLoss)
12
13 Mkt$pred_d <- ifelse(Mkt$a > Mkt$Close, 'U','D')
14 Mkt$pu <-c( NA, Mkt$pred_d[ - length(Mkt$pred_d) ] )
15
16 # Trade Long
17 Mkt$Long <- ifelse(Mkt$pu == 'U', Mkt$Close - Mkt$Open, NA)
18 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19 #Adj for SLoss
20 if (SLoss < 0) {
21   Mkt$Long <- ifelse(Mkt$p > Mkt$p_c,
22                     ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
23                     Mkt$Long)
24   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25 }
26
27 # Trade Short
28 Mkt$Short <- ifelse(Mkt$pu == 'D', Mkt$Open - Mkt$Close, NA)
29 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
30 #Adj for SLoss
31 if (SLoss < 0){
32   Mkt$Short <- ifelse(Mkt$p < Mkt$p_c,
33                     ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
34                     Mkt$Short)
35   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36 }
37
38 Stats <- calcStats2(Mkt$Long)
39 results[5:7] <- Stats
40
41 Stats <- calcStats2(Mkt$Short)
42 results[8:10] <- Stats
43
44 return(results)
45 }

```

RCode/es\_1.R

### A.2.2 System 1

```

1 ts_1 <- function(Mkt, SLoss, MktName){
2   # Trading system using predictions from ARIMA models. Uses relative
3   # value of the forecast with the previous close
4   #
5   # Mkt: market data
6   # SLoss: stop loss
7   # MktName: market's name for print out
8   # Returns:
9   # results vector.
10
11 results <- createResultsVector(MktName, SLoss)
12

```

```

13 Mkt$p_c <- c( NA, Mkt$Close[ - length(Mkt$Close) ] ) # prev close
14 Mkt$p_p <- c( NA, Mkt$p[ - length(Mkt$p) ] ) # prev pred
15
16 # Trade Long
17 Mkt$Long <- ifelse(Mkt$p_p > Mkt$p_c, Mkt$Close - Mkt$Open, NA)
18 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19 #Adj for SLoss
20 if (SLoss < 0) {
21   Mkt$Long <- ifelse(Mkt$p_p > Mkt$p_c,
22                     ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
23                     Mkt$Long)
24   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25 }
26
27 # Trade Short
28 Mkt$Short <- ifelse(Mkt$p_p < Mkt$p_c, Mkt$Open - Mkt$Close, NA)
29 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
30 #Adj for SLoss
31 if (SLoss < 0){
32   Mkt$Short <- ifelse(Mkt$p_p < Mkt$p_c,
33                     ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
34                     Mkt$Short)
35   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36 }
37
38 Stats <- calcStats2(Mkt$Long)
39 results[5:7] <- Stats
40
41 Stats <- calcStats2(Mkt$Short)
42 results[8:10] <- Stats
43
44 return(results)
45 }

```

RCode/ts\_1.R

### A.2.3 System 2

```

1 ts_2 <- function(Mkt, SLoss, MktName){
2   # Trading system using predictions from ARIMA models. Uses
3   # relative value of the forecast and the previous forecast
4   #
5   # Mkt: market data
6   # SLoss: stop loss
7   # MktName: market's name for print out
8   # Returns:
9   # results vector.
10
11   results <- createResultsVector(MktName, SLoss)
12
13   Mkt$p_p <- c( NA, Mkt$p[ - length(Mkt$p) ] ) # prev prediction
14   Mkt$p_p2 <- c( NA, Mkt$p_p[ - length(Mkt$p_p) ] ) # prev prediction
15

```

```

16 # Trade Long
17 Mkt$Long <- ifelse(Mkt$p_p > Mkt$p_p2, Mkt$Close - Mkt$Open, NA)
18 results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
19 #Adj for SLoss
20 if (SLoss < 0) {
21   Mkt$Long <- ifelse(Mkt$p_p > Mkt$p_p2,
22                     ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
23                     Mkt$Long)
24   results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
25 }
26
27 # Trade Short
28 Mkt$Short <- ifelse(Mkt$p_p < Mkt$p_p2, Mkt$Open - Mkt$Close, NA)
29 results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
30 #Adj for SLoss
31 if (SLoss < 0){
32   Mkt$Short <- ifelse(Mkt$p_p < Mkt$p_p2,
33                     ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
34                     Mkt$Short)
35   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
36 }
37
38 Stats <- calcStats2(Mkt$Long)
39 results[5:7] <- Stats
40
41 Stats <- calcStats2(Mkt$Short)
42 results[8:10] <- Stats
43
44 return(results)
45 }

```

RCode/ts\_2.R

### A.2.4 Categorical Label

```

1 ts_4 <- function(Mkt, SLoss, MktName){
2   # trading system based on prediction from ANN working with categorical
3   # label with valued U or D
4   #
5   # Mkt: market data
6   # SLoss: stop loss
7   # MktName: market's name for print out
8   #
9   # Returns:
10  # results vector.
11
12  results <- createResultsVector(MktName, SLoss)
13  Mkt$p_p <- c( NA, Mkt$pred[ - length(Mkt$pred) ] ) # prev pred
14
15  # Trade Long
16  Mkt$Long <- ifelse(Mkt$p_p == "U", Mkt$Close - Mkt$Open, NA)
17  results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
18  #Adj for SLoss

```

```

19   if (SLoss < 0) {
20     Mkt$Long <- ifelse(Mkt$p_p == "U",
21                       ifelse((Mkt$Low-Mkt$Open) < SLoss, SLoss, Mkt$Long),
22                       Mkt$Long)
23     results["LongPL"] <- round(sum(Mkt$Long, na.rm=TRUE))
24   }
25
26   # Trade Short
27   Mkt$Short <- ifelse(Mkt$p_p == "D", Mkt$Open - Mkt$Close, NA)
28   results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
29   #Adj for SLoss
30   if (SLoss < 0){
31     Mkt$Short <- ifelse(Mkt$p_p == "D",
32                       ifelse((Mkt$Open-Mkt$High) < SLoss, SLoss, Mkt$Short),
33                       Mkt$Short)
34     results["ShortPL"] <- round(sum(Mkt$Short, na.rm=TRUE))
35   }
36
37   Stats <- calcStats2(Mkt$Long)
38   results[5:7] <- Stats
39
40   Stats <- calcStats2(Mkt$Short)
41   results[8:10] <- Stats
42
43   return(results)
44 }

```

RCode/ts\_4.R

### A.3 Utility Code

```

1 nm <- c("DAX", "CAC", "FTSE", "Dow", "Nikkei", "AORD")
2
3 createResultsVector <- function(MktName, SLossValue){
4   # Function to create results vector
5   #
6   # Args:
7   #   SLoss: stop loss value
8   #   MktName: market's name for print out
9   #
10  # Returns:
11  #   results vector.
12
13  results <- rep(0,11)
14  nam <- c("Mkt",           # 1. Name of Mkt
15          "S Loss",        # 1. Name of Mkt
16          "LongPL",        # 1. Name of Mkt
17          "ShortPL",       # 1. Name of Mkt
18          "L Win %",       # 1. Name of Mkt
19          "L Trades",      # 1. Name of Mkt
20          "Av L PL",       # 1. Name of Mkt
21          "S Win %",       # 1. Name of Mkt

```

```

22         "S Trades",      # 1. Name of Mkt
23         "Av S PL",
24         "misc")          # 1. Name of Mkt
25     names(results) <- nam
26     results["Mkt"] <- MktName
27     results["S Loss"] <- SLossValue
28     return(results)
29 }
30
31 calcStats <- function(x){
32     # Function to calculate trade stats
33     #
34     # Args:
35     #   x - data set
36     #
37     # Returns:
38     #   results vector.
39
40     results <- 1:3
41     v <- na.omit(x)
42
43     # Win %
44     wins <- length(v[v>0])
45     losses <- length(v[v<0])
46     results[1] <- round(wins/(wins+losses)*100)
47
48     # Num Trades
49     results[2] <- length(v)
50
51     # Av Long PL
52     results[3] <- round(sum(v) / length(v))
53
54     return(results)
55 }
56
57 calcStats2 <- function(x){
58     # Function to calculate trade stats
59     #
60     # Args:
61     #   x - data set
62     #
63     # Returns:
64     #   results vector.
65     #browser()
66     results <- 1:3
67     #v <- na.omit(x)
68     v <- x
69
70     # Win %
71     wins <- sum(v>0,na.rm=T)
72     losses <- sum(v<0,na.rm=T)
73     results[1] <- round(wins/(wins+losses)*100)
74
75     # Num Trades
76     results[2] <- wins+losses

```

```

77
78 # Av Long PL
79 results[3] <- round(sum(v,na.rm=T) / (wins+losses))
80
81 return(results)
82 }
83
84 calcWinPer <- function(x){
85   wins <- length(x[x>0])
86   losses <- length(x[x<0])
87   return(wins/(wins+losses)*100)
88 }
89
90 calcAverageWin <- function(x){
91   wins <- length(x)
92   winpl <- sum(x, na.rm=T)
93   return((winpl/wins))
94 }
95
96 calcNumTrades <- function(x){
97   return(length(na.omit(x)))
98 }
99
100 savepdf <- function(file, width=16, height=10)
101 {
102   fname <- paste("../Figures/",file,".pdf",sep="")
103   pdf(fname, width=width/2.54, height=height/2.54,
104       pointsize=10)
105   par(mgp=c(2.2,0.45,0), tcl=-0.4, mar=c(3.3,3.6,1.1,1.1))
106 }
107
108
109 print_xt <- function(dat,dig,cap,lab,al,filename,inclrnam){
110   xt <- xtable(
111     dat,
112     digits = dig,
113     caption = cap,
114     label = lab
115   )
116   al <- c('l','l')
117   al <- c(al, rep('c',ncol(dat)-1))
118   align(xt) <- al
119   print(xt,
120     file=filename,
121     include.rownames=inclrnam,
122     caption.placement = "top",
123     hline.after=NULL,
124     add.to.row=list(pos=list(-1,0, nrow(xt)),
125                       command=c('\\toprule ', '\\midrule ', '\\bottomrule ')))
126
127 }
128
129
130 # subtract 2 data frames
131 # df2 from df1

```



```

132 sub_df <- function(df1, df2){
133
134   nc <- ncol(df1)
135   ln <- nrow(df1)
136   dfres <- df1
137
138   for(i in 1:ln){
139     for(j in 2:nc){
140       dfres[i,j] <- as.numeric(df1[i,j]) - as.numeric(df2[i,j])
141     }
142   }
143   return(dfres)
144 }
145
146 # subtract 2 data frames - rtn fewer cols
147 # df2 from df1
148 sub_df_av_pl <- function(df1, df2){
149
150   nc <- ncol(df1)
151   ln <- nrow(df1)
152   dfres <- df1
153   for(i in 1:ln){
154     for(j in 2:nc){
155       dfres[i,j] <- as.numeric(df1[i,j]) - as.numeric(df2[i,j])
156     }
157   }
158   dfres <- dfres[,c(1,7,10)]
159   colnames(dfres) <- c('Mkt','Diff in Mean Long PL','Diff in Mean Short PL')
160   return(dfres)
161 }
162
163
164 # -----
165 # ----- CHAPTER 4 -----
166 # -----
167
168 # ----- Follow Previous -----
169 run_NaiveReversePrev <- function(fil,SLoss, nm){
170   df10 <- as.data.frame(matrix(seq(11),nrow=1,ncol=11))
171   for(i in 1:length(fil)){
172     Dax <- read.csv(fil[i],stringsAsFactors=F)
173     a <- NaiveReversePrev(Dax, SLoss, nm[i])
174     df10 <- rbind(df10, a)
175   }
176   df.name <- names(a)
177   names(df10) <- df.name
178   df10 <- df10[-1,]
179   return(df10)
180 }
181
182 # -----
183 # ----- CHAPTER 5 -----
184 # -----
185 # ----- Arima Ann Predicting Up/Dn - Categorical -----
186 # a. Categorical

```

```

187 ts_4_fnc_ar <- function(fil,SLoss,nm){
188   for(i in 1:length(fil)){
189     Mkt <- read.csv(fil[i],stringsAsFactors=F)
190     Mkt_p <- Mkt[,c(1,2,3,4,5)]
191     Mkt_p$pred <- Mkt$pred
192     colnames(Mkt_p) <- c("Date","Open", "High","Low","Close","pred")
193     a <- ts_4(Mkt_p, SLoss,nm[i])
194     df10 <- rbind(df10, a)
195   }
196   df.name <- names(a)
197   names(df10) <- df.name
198   df10 <- df10[-c(1),]
199   return(df10)
200 }
201
202
203 # -----
204 # ----- Arima Ann Predicting Up/Dn - 01 -----
205 ts_3_fnc_ar <- function(fil,nm,ts1){
206   for(i in 1:length(fil)){
207     Mkt <- read.csv(fil[i],stringsAsFactors=F)
208     Mkt_p <- Mkt[,c(1,2,3,4,5,18)]
209     colnames(Mkt_p) <- c("Date","Open", "High","Low","Close","p")
210     a <- ts_3(Mkt_p, 0, nm[i])
211     df10 <- rbind(df10, a)
212   }
213   df.name <- names(a)
214   names(df10) <- df.name
215   df10 <- df10[-c(1),]
216   return(df10)
217 }
218
219 # bit of fiddling for ANN
220 ts_3a_fnc_ar <- function(fil,nm,ts1){
221   for(i in 1:length(fil)){
222     Mkt <- read.csv(fil[i],stringsAsFactors=F)
223     Mkt_p <- Mkt[,c(1,2,3,4,5,18)]
224     colnames(Mkt_p) <- c("Date","Open", "High","Low","Close","p")
225     a <- ts_3a(Mkt_p, 0, nm[i])
226     df10 <- rbind(df10, a)
227   }
228   df.name <- names(a)
229   names(df10) <- df.name
230   df10 <- df10[-c(1),]
231   return(df10)
232 }

```

## Appendix B

# Technical Indicators

### B.1 Moving Average Convergence Divergence (MACD)

MACD is a widely used technical indicator which attempts to detect the early stage of a market trend. It is calculated by subtracting a long exponential moving average (EMA) from a shorter one. The EMA is calculated as follows:

$$EMA(n)_t = \frac{2}{n+1}(P_t - EMA_{t-1}) + EMA_{t-1}$$

Where  $P_t$  is the closing price of a market on day  $t$  and  $n$  is the number of periods used in calculating the moving average. MACD itself is calculated as:

$$MACD_t = EMA(s)_t - EMA(l)_t$$

where  $EMA(s)_t$  is the short moving average and  $EMA(l)_t$  is the long one. In addition an EMA of the MACD itself is calculated in order to generate trade signals and is often referred to as the “trigger line”. Thus a particular MACD trading rule is often expressed in the form  $MACD(s, l, k)$  where  $s$  is the number of periods of the short EMA,  $l$  the number of periods of the long EMA and  $k$  the period used to average the MACD for the trigger line.

### B.2 Aroon Indicator

The Sanskrit word aroon means ”dawn’s early light” and the Aroon indicator attempts to show when a new market trend is dawning (Chande and Kroll, 1994). The indicator

is made up of two lines (Aroon Up and Aroon Down) that measure how long it has been since the highest high and lowest low has occurred within an  $n$  period range, and an oscillator value that is the difference between the two. Aroon Up (or Down) is the elapsed time, expressed as a percentage, between today and the highest (or lowest) price in the last  $n$  periods. If the current price is a new high (or low) Aroon Up (or Aroon Down) will be 100. Each subsequent period without another new high (or low) causes Aroon up (down) to decrease by  $(1 / n) \times 100$ .

$$AroonUp = 100 * \left( \frac{n - PeriodSinceHighestHigh}{n} \right)$$

$$AroonDown = 100 * \left( \frac{n - PeriodSinceLowestLow}{n} \right)$$

When the Aroon Up is between a value of 70 and 100 it indicates an upward trend. When the Aroon Down is staying between 70 and 100 then it indicates a downward trend. A strong upward trend is indicated when the Aroon Up is above 70 while the Aroon Down is below 30. Likewise, a strong downward trend is indicated when the Aroon Down is above 70 while the Aroon Up is below 30. Also the crossing over of the lines is significant. When the Aroon Down crosses above the Aroon Up, it indicates a weakening of the upward trend (and vice versa).

The Aroon Oscillator signals that an upward trend is occurring when it is above zero and a downward trend is occurring when it falls below zero. The farther away the oscillator is from the zero line, the stronger the trend.

### B.3 Parabolic Stop-and-Reverse (SAR)

The Parabolic Stop-and-Reverse (SAR) is a quite complex indicator developed by Welles Wilder in 1978 (Wilder, 1978). The calculation for SAR in rising and falling markets are different and are usually presented separately.

If the market is rising SAR is calculated as:

$$\text{Current SAR} = \text{Prior SAR} + \text{Prior AF}(\text{Prior EP} - \text{Prior SAR})$$

where:

- Prior SAR is the SAR value for the previous time period, for example the previous day's value.
- Extreme Point (EP) is the highest high of the current trend.
- Acceleration Factor (AF) starts at 0.02, and increases by 0.02 each time the market makes a new high (Extreme Point). The maximum value the AF can reach is 0.20, at which point it is capped.

Note: SAR can never be greater than the value of the previous two periods' lows. Should SAR be above one of those lows, it is set to the lowest of the two.

If the market is falling SAR is calculated as:

$$\text{Current SAR} = \text{Prior SAR} - \text{Prior AF}(\text{Prior SAR} - \text{Prior EP})$$

Note: SAR can never be less than the value of the previous two periods' highs. Should SAR be less than one of those highs, it is set to the lowest of the two.

## B.4 Stochastic

The stochastic oscillator measures where a particular close price is in relation to the highest high and lowest low in the range under study. It is usually drawn on a chart as two lines, one is %K and the other is its moving average usually called %D.

The calculation of the stochastic involves four variables:

1. %K Period - the number of periods used in the calculation (see below).
2. %K Smoothing Period - smoothing period applied to %K.
3. %D Period - the number of time periods used in the moving average of %K to generate %D.
4. %D Method - the moving average method used to calculate %D.

%K is calculated as follows:

$$\%K = 100 * \left( \frac{\text{Today's Close} - \text{Lowest Low in n Periods}}{\text{Highest High in n Periods} - \text{Lowest Low in n Periods}} \right)$$

The stochastic is used in a variety of ways. One popular method is to buy when the stochastic falls below a particular level then rises back above that level (and vice versa for a short trade). An alternative technique is to buy when the %K rises above %D and sell when it falls under %K.

## B.5 Rate of Change(ROC)

The Rate of Change or ROC indicator highlights the difference between a particular price (e.g. closing price) and the same price a number of periods previously. This value can be expressed in absolute terms or a percentage rise or fall. The calculation is as follows:

$$ROC = 100 * \left( \frac{\text{Today's Close} - \text{Today's Close n Periods Ago}}{\text{Today's Close n Periods Ago}} \right)$$

The ROC can be calculated from a wide range of time periods, with 12 and 25 days being the most common. The ROC is typically used as an over-bought / over-sold indicator to provide evidence for when a market turn maybe expected.

## Appendix C

# Summary of Results

### C.1 Chapter 4 Results

TABLE C.1: Chapter 5 DAX Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	-1640	-1505	-1	-1
Drift Method	2310	2445	1	2
Exponential Smoothing	-2029	-1894	-1	-1
ARIMA - System 1	-1285	-2522	-5	-9
ARIMA - System 2	733	-505	3	-2
ARIMA/ANN Closing Price System 1	-446	-645	-1	-2
ARIMA/ANN Closing Price System 2	3283	3110	6	7
ARIMA/k-NN Closing Price System 1	12	-174	0	0
ARIMA/k-NN Closing Price System 2	489	731	1	2
ARIMA/ANN Up/Down	199	0	0	NaN
ARIMA/k-NN Up/Down	-1515	-1714	-3	-4
ARIMA/ANN Up/Down Stop Loss	-444	-1122	-1	-2
ARIMA/SVM Up/Down	-123	-322	0	-1

TABLE C.2: Chapter 4 CAC Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Naive Long	-6725	0	-2	0
Naive Long 2	-1667	0	0	0
Reverse Prev	940	7810	1	4
Reverse Prev Stop Loss	1335	8165	1	5
SMA 5	-3952	2338	-2	1
SMA 25	-5058	1615	-2	1
SMA 50	-5323	1029	-3	1
SMA 100	-2363	3188	-1	2
SMA 200	-1219	3923	-1	3
SMA 100	-172	5178	0	4
SMA 100	-1822	4658	-1	3
MACD	-4153	2188	-2	1
Aroon	-1638	4919	-1	4
Aroon Stop Loss	-1224	6086	-1	5
SAR	-5584	1034	-3	1
MACD Reversal	-545	2657	-1	5
Stoch	-4540	1817	-3	1
Stoch Stop Loss	-3493	2730	-2	2
ROC	952	956	2	2
Daily Breakout	3491	6955	2	4
90% Quantile Breakout	2647	5085	2	3
Hammer Candlestick	-793	0	-5	0
Engulfing Candlestick	-319	228	-2	1
Engulfing Candlestick in Trend	-118	-666	-3	-11
Doji Candlestick	-747	-326	-6	-2



TABLE C.3: Chapter 4 FTSE Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Naive Long	149	0	0	0
Naive Long 2	86	0	0	0
Reverse Prev	4284	4115	3	2
Reverse Prev Stop Loss	5537	5200	3	3
SMA 5	-4724	-5331	-2	-3
SMA 25	-1013	-1940	0	-1
SMA 50	-2226	-2769	-1	-2
SMA 100	-889	-1692	0	-1
SMA 200	-158	-835	0	-1
SMA 100	1114	6303	1	5
SMA 100	-885	1892	0	1
MACD	63	-839	0	0
Aroon	3042	5715	2	5
Aroon Stop Loss	3091	8015	2	7
SAR	-1141	-1663	-1	-1
MACD Reversal	2080	1649	4	3
Stoch	-73	-744	0	0
Stoch Stop Loss	1640	1424	1	1
ROC	1147	1880	2	4
Daily Breakout	13189	18481	7	12
90% Quantile Breakout	10758	15295	7	10
Hammer Candlestick	834	0	4	0
Engulfing Candlestick	-1721	1185	-4	3
Engulfing Candlestick in Trend	-1217	-782	-8	-3
Doji Candlestick	-697	418	-8	3

TABLE C.4: Chapter 4 Dow Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Naive Long	9816	0	3	0
Naive Long 2	5219	0	1	0
Reverse Prev	15799	6047	10	3
Reverse Prev Stop Loss	-8571	-14604	-5	-8
SMA 5	408	-9630	0	-6
SMA 25	1138	-9204	1	-7
SMA 50	5478	-5876	3	-4
SMA 100	2576	-8220	1	-6
SMA 200	6378	-4567	3	-4
SMA 100	-18212	-8229	-9	-6
SMA 100	-11771	-14696	-6	-11
MACD	5592	-5190	3	-3
Aroon	12131	3811	7	3
Aroon Stop Loss	-5922	-9341	-3	-8
SAR	-1301	-11112	-1	-7
MACD Reversal	3882	-807	7	-2
Stoch	867	-9414	0	-5
Stoch Stop Loss	-13969	-27388	-8	-16
ROC	8517	3396	16	6
Daily Breakout	-19598	-28337	-11	-17
90% Quantile Breakout	-30262	-34854	-24	-28
Hammer Candlestick	2097	0	24	0
Engulfing Candlestick	-770	-3662	-4	-28
Engulfing Candlestick in Trend	202	-1154	4	-11
Doji Candlestick	-763	-2869	-5	-10

TABLE C.5: Chapter 4 Nikkei Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Naive Long	-18125	0	-5	0
Naive Long 2	-2712	0	-1	0
Reverse Prev	2324	20486	1	12
Reverse Prev Stop Loss	18137	27909	10	17
SMA 5	3078	20401	2	13
SMA 25	-7878	10770	-4	7
SMA 50	-6054	11408	-4	7
SMA 100	-6235	8381	-4	5
SMA 200	-5928	6836	-4	4
SMA 100	8258	33882	5	20
SMA 100	2550	25582	2	15
MACD	-4078	14064	-2	8
Aroon	-4852	12013	-3	10
Aroon Stop Loss	3153	22177	2	18
SAR	-5767	12424	-3	8
MACD Reversal	199	2828	0	6
Stoch	-10591	7802	-6	5
Stoch Stop Loss	1647	17977	1	10
ROC	2971	2546	6	5
Daily Breakout	31988	43554	19	27
90% Quantile Breakout	23606	31830	16	20
Hammer Candlestick	-2202	0	-15	0
Engulfing Candlestick	-3823	-1166	-39	-11
Engulfing Candlestick in Trend	-1522	-1733	-59	-32
Doji Candlestick	1296	-2944	12	-22

TABLE C.6: Chapter 4 AORD Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Naive Long	972	0	0	0
Naive Long 2	2229	0	1	0
Reverse Prev	1264	237	1	0
Reverse Prev Stop Loss	2320	1085	1	1
SMA 5	5009	3929	3	3
SMA 25	3701	2674	2	2
SMA 50	2804	1864	1	1
SMA 100	2688	1521	1	1
SMA 200	2574	1616	1	2
SMA 100	4008	3730	2	3
SMA 100	2881	2149	1	2
MACD	2563	1569	1	1
Aroon	3735	3540	2	3
Aroon Stop Loss	3786	4159	2	4
SAR	2071	1097	1	1
MACD Reversal	-319	-584	-1	-1
Stoch	2839	1780	2	1
Stoch Stop Loss	3028	1974	2	1
ROC	271	1325	1	2
Daily Breakout	17225	19184	10	13
90% Quantile Breakout	16730	19357	9	12
Hammer Candlestick	-809	0	-3	0
Engulfing Candlestick	-6	-600	0	-3
Engulfing Candlestick in Trend	-49	-27	-1	0
Doji Candlestick	-115	195	-1	2

## C.2 Chapter 5 Results

TABLE C.7: Chapter 5 DAX Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	-1640	-1505	-1	-1
Drift Method	2310	2445	1	2
Exponential Smoothing	-2029	-1894	-1	-1
ARIMA - System 1	-1285	-2522	-5	-9
ARIMA - System 2	733	-505	3	-2
ARIMA/ANN Closing Price System 1	-446	-645	-1	-2
ARIMA/ANN Closing Price System 2	3283	3110	6	7
ARIMA/k-NN Closing Price System 1	12	-174	0	0
ARIMA/k-NN Closing Price System 2	489	731	1	2
ARIMA/ANN Up/Down	199	0	0	NaN
ARIMA/k-NN Up/Down	-1515	-1714	-3	-4
ARIMA/ANN Up/Down Stop Loss	-444	-1122	-1	-2
ARIMA/SVM Up/Down	-123	-322	0	-1

TABLE C.8: Chapter 5 CAC Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	-1086	3553	-1	2
Drift Method	-2422	2217	-1	2
Exponential Smoothing	-266	4048	0	2
ARIMA - System 1	872	167	3	1
ARIMA - System 2	545	-80	2	0
ARIMA/ANN Closing Price System 1	532	1527	2	2
ARIMA/ANN Closing Price System 2	-1832	-816	-3	-2
ARIMA/k-NN Closing Price System 1	-684	312	-1	1
ARIMA/k-NN Closing Price System 2	-1458	-441	-3	-1
ARIMA/ANN Up/Down	-84	912	0	2
ARIMA/k-NN Up/Down	-377	619	-1	1
ARIMA/ANN Up/Down Stop Loss	-431	689	-1	1
ARIMA/SVM Up/Down	-140	855	0	1

TABLE C.9: Chapter 5 FTSE Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	1680	345	1	0
Drift Method	-518	-1853	0	-1
Exponential Smoothing	3866	2531	3	2
ARIMA - System 1	990	-249	4	-1
ARIMA - System 2	941	-383	3	-2
ARIMA/ANN Closing Price System 1	625	-624	1	-2
ARIMA/ANN Closing Price System 2	1092	-182	2	0
ARIMA/k-NN Closing Price System 1	699	-550	1	-1
ARIMA/k-NN Closing Price System 2	-388	-1662	-1	-4
ARIMA/ANN Up/Down	1400	151	2	0
ARIMA/k-NN Up/Down	-266	-1515	-1	-3
ARIMA/ANN Up/Down Stop Loss	81	-1162	0	-2
ARIMA/SVM Up/Down	2115	866	5	1

TABLE C.10: Chapter 5 Dow Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	8356	-2126	7	-1
Drift Method	5416	-5066	3	-4
Exponential Smoothing	12901	2419	8	2
ARIMA - System 1	1539	-3356	7	-11
ARIMA - System 2	2598	-2221	9	-10
ARIMA/ANN Closing Price System 1	2846	-3979	5	-9
ARIMA/ANN Closing Price System 2	3829	-2942	7	-7
ARIMA/k-NN Closing Price System 1	4436	-2389	11	-4
ARIMA/k-NN Closing Price System 2	2969	-3411	5	-9
ARIMA/ANN Up/Down	5218	-1607	6	-10
ARIMA/k-NN Up/Down	3211	-3614	6	-8
ARIMA/ANN Up/Down Stop Loss	5475	-1922	11	-4
ARIMA/SVM Up/Down	2138	-4686	10	-6

TABLE C.11: Chapter 5 Nikkei Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	-32	10646	0	6
Drift Method	-6939	3739	-4	3
Exponential Smoothing	-2741	7937	-2	5
ARIMA - System 1	4268	3071	21	13
ARIMA - System 2	179	-916	1	-4
ARIMA/ANN Closing Price System 1	913	2039	2	4
ARIMA/ANN Closing Price System 2	-4485	-3229	-9	-7
ARIMA/k-NN Closing Price System 1	-66	1060	0	2
ARIMA/k-NN Closing Price System 2	-2916	-1660	-6	-4
ARIMA/ANN Up/Down	234	1360	12	1
ARIMA/k-NN Up/Down	2707	3834	6	8
ARIMA/ANN Up/Down Stop Loss	4021	2804	9	6
ARIMA/SVM Up/Down	9	1135	0	2

TABLE C.12: Chapter 5 AORD Results

Methodology	LongPL	ShortPL	Av L PL	Av S PL
Mean Method	-1333	-2149	-1	-1
Drift Method	1476	660	1	1
Exponential Smoothing	645	-171	0	0
ARIMA - System 1	635	-247	2	-1
ARIMA - System 2	811	-117	3	0
ARIMA/ANN Closing Price System 1	-3036	-371	-5	-1
ARIMA/ANN Closing Price System 2	-2783	-137	-5	0
ARIMA/k-NN Closing Price System 1	497	3162	1	7
ARIMA/k-NN Closing Price System 2	-3449	-804	-6	-2
ARIMA/ANN Up/Down	-2712	-47	-3	-12
ARIMA/k-NN Up/Down	-2445	220	-4	1
ARIMA/ANN Up/Down Stop Loss	254	245	0	1
ARIMA/SVM Up/Down	-2364	301	-4	1

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