

ERASMUS UNIVERSITY ROTTERDAM
ERASMUS SCHOOL OF ECONOMICS
MSc Economics & Business
Master Thesis Financial Economics



Heterogeneous behaviour in European stock market indices

Author: J.A.N. de Groot
Student number: 316387jg
Thesis supervisor: Prof. Dr. W.F.C. Verschoor
Finish date: 1 December 2011

Abstract

This thesis empirically tests an heterogeneous agent model containing a fundamentalist, chartists and noise trading regime on a sample of the AEX, BEL20, CAC40, DAX30 and FTSE100 stock index. The results indicate the model to be insufficient in explaining price movements of these indices. However there is reason to believe these regimes occupy the market and the fundamentalist and chartist regime interchange agents expectations. The influence of the market maker of the London Stock Exchange is not prominent. Probably through the weekly frequency of the data. Movements in agents expectations indicate the chartist believes to have big influence on price movements.

Preface and Acknowledgements

My name is Jack de Groot and I am 24 years of age. In the year 2007 I started my bachelor Economics and Business Economics at the Erasmus University in Rotterdam. After three years I graduated with a thesis on stock market price reactions on unexpected dividend announcements. In September 2010 I started my Master study at the same University, specializing in Financial Economics. This thesis is the last step towards graduating the previously stated study.

In both my Bachelor and Master study I have followed different courses on Behavioural Economics and Finance. This relatively new step in theory has fascinated me. Putting back some human behaviour in the assumed rational participators of financial markets seems like logical step in the evolution of financial theory. Especially when roughly testing this vision on the economic environment on the day of writing this thesis. My bachelor thesis on price reactions following dividend announcements was a first taste of human behaviour in the market. This thesis goes one step further in trying to find different behaviour in within the European financial market.

I would like to thank prof. dr. W.F.C. Verschoor for his advice and feedback in the writing process of this thesis. I would also like to thank dr. R.J.C. Zwinkels in supporting me in testing the statistical model. Special thanks goes out to my father for his advice and support. And also thanks to my family, girlfriend, friends and all the people that supported me in writing this thesis.

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1 Introduction

Since the second half of the 20th century financial and economic theory has pretty much been dominated by the ideas of efficient markets and rational agents. The rational type of agents were considered to be the only ones capable to survive in the economic environment. Because of this proclaimed survival bias theories and model could be created based on the approximation of the rational. At the last part of the 20th century and the beginning of the 21st century the influence of agents that do not act fully rational came back into account. The assumptions underlying the survival hypotheses seemed to be to constraining when they were put in real economic environments.

This change of scope has put forth new light on human behaviour in economic and financial environments. The influence from psychology has played a great role in these new kind of studies. New models which try to explain economic and financial phenomena were found creation within the context of behavioural economics. These models came in various forms, because there are few ways to be rational but many to be irrational. The first years of model development within financial markets have been characterised by constructing and calibrating models to fit stylised facts of the financial markets. In the period this thesis is written many models based on heterogeneous agents with bounded rationality have known creation. After establishment within computer simulated worlds some of these models have been taken towards the real financial world. The most popular ground for this step in evolution is probably the foreign exchange market. The enormous amounts traded each day within the FOREX markets and the skewed distribution of the exchange rates indicate the markets are not fully efficient. The FOREX market is not only known for speculation. They contain traders which put possible profits on low(er) priority and survive because they are (solely) depended on the competition and speculation within the markets.

Few attempts have been made to test the heterogeneous agent models (HAMs) on stock market data. The made attempts have focused mainly on stock market indices and in particular the United States. Other scopes have been towards upcoming economies. One of the few attempts is the study of Boswijk et al. (2007) which tries to explain movements in the S&P500 index. They estimate a form of the adaptive believe system (ABS) created by Brock and Hommes(1997, 1998) which contains a mean reverting fundamental and a trend following chartist regime on movements in the S&P500 index between 1871 and 2003. The research of Chiarella et al. (2010) also tried to estimate changes in the S&P500 price index with adjusted and extended version of the ABS model. Next to the fundamental and an adjusted long term orientated chartist regime they added a noise trader regime. In line with the extensions put forth by Chiarella and He (2003) they also investigated possible influence of market makers on price adjustments of the index.

The study of de Jong et al. (2009) used the mechanism of the ABS to try to explain and forecast price movements in the Hang Seng and Bangkok S.E.T indices in the period surrounding the Asian crisis. Instead of explaining movements in the difference between price and the theoretical fundamental price they directly try to explain movements in price with a model containing fundamentalists, chartists and internationalists. This last group of traders proxies the international co-movements of fundamentals underlying markets. Empirical research on agent based models still remain quite scarce.

To my knowledge, there has been no research on the fitness of HAMs on European indices. European markets are quite interesting given their movements and integration. Take the recent credit crisis for example which shows the downfall of Greece has influence on other European countries. The historical position of Europe as a global player is also fascinating as the markets are influenced and possibly strengthened. Events like black Monday which started in Hong Kong and found its way through Europe towards the American market. The main question this thesis tries to answer is, if movements in European stock market indices can be explained by heterogeneity of the agents that operate within these markets. More specifically I will try to investigate if movements in European stock market indices can be explained by heterogeneity in the strategies of the participants which operate within them.

This thesis hypothesizes the movements in European stock indices can be approximated by the heterogeneous agent model used in the research of Chiarella et al. (2010). This model contains a variety of trading regimes which are theoretically grounded in behavioural finance and has a relatively more realistic approximation of the financial market. The edge in realism comes forth out of the addition of a market maker in influencing the price movements. As previously stated the model contains fundamentalists, chartists, noise traders, a markets maker and a switching mechanism. The HAM is approximated on a sample of compatible European stock indices. The compatibility constraints are the European character, listing on the London Exchange, and the inclusion in DataStream of the price and price earnings ratios of the indices. The indices which were found compatible consist of the AEX, BEL20, CAC40, DAX30 and FTSE100 stock index. Previous empirical studies on stock indices have little variety in their use of different indices. Most studies investigate only one or two indices, explaining heterogeneity over lengthy periods, but not checking their results in (many) other markets. This thesis tries to test the robustness of the used model and benchmark past study results by testing the model on a relatively diverse sample in the sense of number of indices and their length. Not constraining the results to a single index nor period. Checking overall influence of different agents trading in the European market.

The thesis will continue in chapter 2 with a historical overview of the countered rational and efficient theories, describe the survival within financial markets, and give different types of approximation of human behaviour with heterogeneous agents models. This within the sight of validation of the scope of this thesis and its choice of model. The chapter will end with an establishment within recent empirical studies on heterogeneous agents. The chosen adaptive believe system with the adjustment which were introduced by Chiarella and He (2003) will be explained in chapter 3. The sample and methodology of this study will be discussed in chapter 3. The results can be found in chapter 5 and chapter 6 will conclude.

2 Theory on Behavioural Finance and Heterogeneous Agents

The theory discussed in this chapter has multiple aims. The first paragraph sketches theory which until shortly back in history has been considered the norm. This is followed by an explanation on the shortcomings of these theories when they were put into practice. This in stressing the importance on testing heterogeneous behaviour in and influence on financial markets. The second part of the chapter tries to put this thesis in place in comparison with other studies on HAMs and especially the ones testing the models on prices of stock indices.

2.1 Rational Agents within Efficient Markets

There has been acceptance about the fact that not all people act rational. But according to neoclassical economic theory agents do act rational as a group. This should be caused by a survival of the fittest within the market. And so the behaviour of consumers, investors and firms can be described as if they are rational when estimating price movements. The survival of the rational agents in evolutionary competition within the financial market, and the disappearance of the non-rational is known as the Friedman Hypothesis (Friedman 1953). When for instance a stock is getting popular because of a fortune tellers prediction, so (assuming) without any fundamental change, this does not have influence on stock prices for a long period. On the short run demand goes up and prices will grow above their theoretical value. Rational agents get aware of the overvaluation, sell (or go short) in the stock and take an opposite position in a comparable stock. With this position they take advantage of a free lunch¹. Rational agents drive the overall demand down and the price back to fundamentals. Non-rational agents have lost money and rational agents gained. The non-rational agents will not survive evolutionary competition within the market.

The rational behaviour of agents is characterized by two aspects (Sargent 1993). The agents form rational expectations and they optimize on the basis of micro economically founded principles according to these rational expectations². Muth (1961) was the first in formulating a specific form of the rational expectations hypothesis (REH). According to REH expectations are formed by informed predictions of future events. The expectations are based on the information available in the market and agents use relevant economic variables and theory for their valuation. They do not however possess the same information, but on average the group of agents make the correct predications. Meaning there are no systematic forecasting errors and the errors that do occur are normally distributed with a mean of zero. Muth (1961) tested REH on a single market and found a partial equilibrium. The REH really became popular when latter Nobel Prize winner Robert E. Lucas Jr. extended it to macro level and applied it to general equilibrium situations (Lucas 1971).

¹ The opposite position in a similar stock is to neutralize fundamental risk. Making use of the mispricing of this risk. Making money without any risk, a *free lunch*.

² So for example, firms may maximize their profits and consumers maximize their utility.

Because of the possibility to take advantage of mispricing, also known as arbitrage, prices can only be shortly over- or undervalued. As valuation should be based on fundamentals, the price is driven by the information on these fundamentals. And so in an efficient market prices should always “fully reflect” available information and new information should be immediately incorporated (Fama 1970, 383). This came to be known as the Efficient Market Hypothesis (EMH). Immediate incorporation of information makes fundamental and technical analysis useless for stock picking. The EMH knows three forms dividing among themselves in the information requirements. EMH’s weakest form only requires past information to be incorporated. This is followed the addition of public information and finally private information. The strongest form has been found to restrictive in reality by the advocates of EMH. It requires the cost of information and trading to be nil to make the additional information worthwhile and that is surely not the case in empirics (e.g. Grossman en Stiglitz (1980) and Fama (1991)).

In the original proposition, efficient markets should follow a random walk as had been suggested by Bachelier (1900) and after the upcoming of the computer empirically tested by Kendall (1953). Information is the main driver of valuation and new information cannot be predicted. Else it concerns past information and should be already incorporated in the price. Later in academic study the assumption for returns to follow a random walk in an efficient market was laid down. Leroy (1973) and Lucas (1978) showed that returns should have some predictability concerning the time-varying risk of fundamental economic conditions. This influence from risk comes from the risk aversion of agents. As people on average do prefer a certain 10 euro’s in comparison to a coin toss chance on 20. In the case of risk aversion a random walk would only point out market inefficiency. A random walk and market efficiency will jointly hold only in the case of risk neutrality.

The optimizing representative rational agent which forms his expectations and valuation on all information available in the market became very popular in the seventies and eighties of the past century. By averaging out human shortcomings, it became easier to form models and theories on basis of homo economicus. You can only be rational in a few ways, but irrationality has wider boundaries. For example, the EMH and the REH put strength on one of the most popular financial valuation tools, namely the Capital Asset Pricing Model (CAPM) of Sharpe (1964) and Lintner (1965). As these models were being formed the time came to test these models in practice. Through the results of empirical tests rationality and market efficiency seemed to get some doubts. Once the CAPM became tested in the financial market it seemed to have insufficient explanatory power. A measure of beta, the coefficient trying to approximate systematic or market risk, seemed insufficient for explaining all the occurring behaviour in prices.

Price to earnings (PE) ratios seemed to have additional explanatory power as low PE stocks outperformed high PE stocks (e.g. Basu(1977) and Basu(1983)). In addition to this anomaly the size of a company, as captured by its market capitalization, seemed to explain a part of the stock returns. This effect remained even when there was a correction for the influence of PE ratios (e.g. Banz (1981) and Basu (1983)). As a last example there seemed to be patterns in returns. In the short run there seemed to be momentum as recent (low) high return stocks were followed by (low) high returns (Jegadeesh 1990). At the long run the opposite pattern found significance. Three to five year outperforming returns were followed by poor returns and vice versa. This could not be explained by CAPM's beta (e.g. DeBondt and Thaler (1985) and Chopra, Lakonishok and Ritter (1992)).

As already stated by Fama (1970), EMH has the problem that it cannot be directly tested without testing some sort of an equilibrium model. When the test is rejected, the joint hypothesis follows in the problem of pointing out the source of the rejection, the model or EMH. Although the valid argument of the joint hypothesis problem and some rational theory explanations for the anomalies³. People were starting to doubt the EMH and REH. Debate was forming in the financial world.

Next to the rejection of EMH and REH based models there were also arguments against the market characteristics. Milgrom and Stokey (1982) argue that if REH is a known fact and markets are efficient nobody wants to trade. Everybody that does want to trade is either acts irrational or has private information. Either way the order will be acted on with quite some scepticism. This no trade theorem is in contrast with the high daily trade volume within real markets. Next to the anomalies concerning return and volume there were also econometrists who claimed the existence of excess volatility in stock prices (e.g. Shiller (1981) and LeRoy and Porter(1981)). They claimed the movements of stock prices were higher than the movements of the fundamentals underlying them. As the models underlying this statement have low power the existence of excess volatility is still debated until this day. Some empirical phenomena put some trust in the possibility of the existence of these large movements. For instance, the stock market crash of 1987 without any large news announcement is hard to explain by homogenous rational agents theory. Another example is the phenomenon of large aggregate movements within the S&P500 that not move together with big news announcements and vice versa (Cutler, Poterba en Summers 1989). All in all the EMH and its rational agents did not seem to explain the financial market perfectly. Slowly terrain was won by a new breed in finance. The more human behaviour based finance.

³ Like the 5-factor model of Fama and French (1992). They claim beta is insufficient in capturing risk and other found "anomalies" are additional proxies for these risks.

2.2 *Limits to arbitrage*

Keynes (1936) already argued in a behavioural sense about the importance of investors' sentiment and market psychology within financial markets. It is difficult to calculate an objective measure cheaply, if at all, from unsure market fundamentals. Information gathering is costly and theory states different fundamentals for valuation. A famous quote out of his work states:

'Investment based on genuine long-term expectation is so difficult as to be scarcely practicable. He who attempts it must surely lead much more laborious days and run greater risks than he who tries to guess better than the crowd how the crowd will behave; and, given equal intelligence, he may make more disastrous mistakes' (Keynes 1936, 157)

The same line of thinking can be found in behavioural finance. This relatively new school of economics believes the Friedman hypothesis does not perfectly hold in empirics. The reason for this hypothesis rejection comes from the idea that arbitrage has its limits. Agents which calculate prices on the basis of fundamentals do not always have the opportunity to take advantage of mispricing thanks to these boundaries. Barberis and Thaler (2003) emphasize that if there is no mispricing there will be no free lunch, but if the EMH does not hold it does not mean there are possibilities for riskless gains.

A first limit to arbitrage lies in the fundamentals itself. To take advantage of mispricing an opposite position must be taken in a substitute asset. Given the rare existence of perfect substitutes⁴, there will be fundamental risk from the possibly mispriced asset and the opposite position which will not be diversified away. The fundamental risk puts constraints on the possibility of a riskless gain.

Second constraints are possible implementation costs like transaction costs and shorting constraints. Some examples of transaction costs are commissions and bid-ask spreads that have to be paid when buying stocks. Shorting constraints are the constraints which make a short position less attractive. Think about stock borrowing fees which are commonly quite low (D'Avolio 2002) but can be much larger. Another example is legal constraints which disable shorting as a whole⁵.

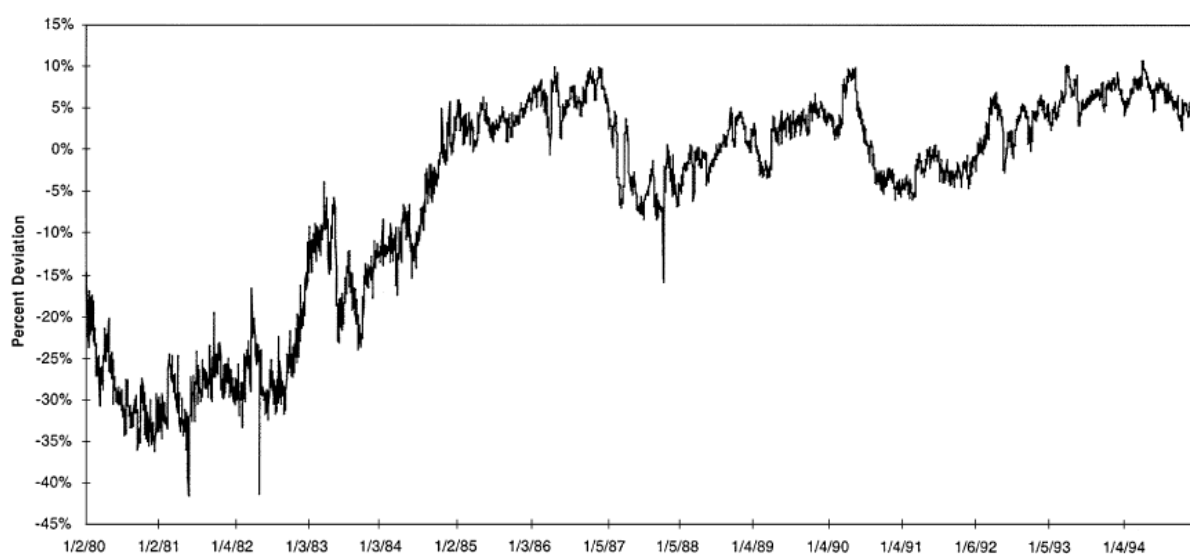
A third limit to arbitrage is noise trader risk. This risk named by DeLong, et al. (1990) is created by the misperception or noise in the mind of less than rational traders. The idea relies on the time it can take prices to return to their fundamental price. In the short run noise traders can worsen valuations even further than they originally did. According to the Friedman hypothesis mispricing will not hold in

⁴ If for example BP has an oil leak it will not have an impact to the same extend on BP's asset prices in comparison with Shells asset prices.

⁵ A lot of pension and mutual funds have this disablement. These are large players and their constraint puts a large part of the investments out of possible arbitrage.

the long run as arbitrage will bring prices back. This should result in gains for arbitrage strategies. Should arbitrageurs however have short run horizons this will not always hold. The risk of having to execute an arbitrage strategy position before it becomes profitable is the risk founded by noise. Because of this risk the noise is able to cause mispricing even in the long run. The reason for short investment horizons is explained by the separation of capital investors and lenders and the professionals who invest this capital (Shleifer and Vishny 1997). If these capital suppliers evaluate the professionals on the basis of short term returns⁶ the short term losses can force the arbitrageur into executing its position early.

Figure 2:1 Log deviations from Royal Dutch/Shell parity (Froot and Dabora 1999)



Empirical evidence for the existence of these limits to arbitrage is scarce thanks to the joint hypothesis problem discussed in chapter 2.1. There are however some persistent market phenomena that can almost only be attributed to market inefficiency. One example is twin shares, which are different shares with a claim on the same cash flows. As share prices can be calculated by discounting these cash flows, the prices should be similar in ratio of the claim these shares have. This is however not the case as can be seen in Figure 2:1 which shows the deviations from fundamental ratio (Froot and Dabora 1999). And with no fundamental risk or high implementation cost this mispricing should be accounted to noise trader risk. A second example is the jump in price when shares are included in indices (e.g. Harris and Gurel (1986), Shleifer (1986) and Wurgler and Zhuravskaya (2002)). There is no fundamental news and a large portion of this jump is found to be permanent. This possible arbitrage opportunity is limited by fundamental risk of the substitute share within the strategy and noise trader risk which is possibly the cause of the jump. A last example is the sale of palm shares by 3Com. At the time at which 5 percent of palm was offered in an initial public offering, 3Com shareholders had a

⁶ Because they do not have the knowledge or confidence in the arbitrage strategies

claim on 1,5 palm share in the future offering of the remaining shares. The initial share price of palm was however higher than 3Com's share price. Given the future claim, the value of 3Com without Palm would have been negative. The problem lied in the inability of the market to meet the demand for shorts(Lamont en Thaler. 2003). The implementation costs where the cause of mispricing.

2.3 Heterogeneous Agent Models

The homogenous representative agent models did not seem to cut it in practice. Thanks to the limits to arbitrage (2.2) there exist opportunities for agents which base their expectations not (only) on the fundamentals that should be underlying prices. The heterogeneity in agents choices in forming market expectations was confirmed by survey studies like Frankel and Froot(1987a, 1987b, 1990). The papers of Frankel and Froot collected survey data on the expectations of bankers, financial specialist and currency traders concerning exchange rates. They used this data to show the change in use of fundamental and technical trading rules to form expectations on the exchange rates. Hinted by their findings they regressed the exchange rates with a bandwagon and a mean-reverting expectations model. The bandwagon expectations model extrapolated past changes in exchange rates as a form of technical trading. The mean-reverting model on the other hand used the long run equilibrium as a proxy for the fundamental rate. They found short horizon expectations (1 week till 1 month) to be different from long run expectations (6-12 months). Respectively expectations could be approximated by the bandwagon and mean-reverting model.

HAMs model different agents instead of using a model per type of agent. Their popularity grew between the middle and the end of nineties in trying to explain stylized facts, like the ones in described in 2.1, through calibration (e.g. Lux (1995, 1997, 1998) and LeBaron, Arthur and Palmer (1999)). The number of HAMs has become abounded in the recent past. Broadly they differ by three important elements, namely their diversity of agents⁷ (heterogeneity), their complexity of the learning process of these agents, and their complexity of agents' interaction. An example of the latter is a random meeting of agents against sophisticated interaction within social networks.

The simplest forms of HAMs have few (two or three) different kinds of agent regimes. The agents switch between the trading rule regimes with simple choice models which encapsulate the interaction and learning process of the agents. Based on the findings of the previously discussed survey papers one type is usually stabilizing and the other destabilizing prices. The stabilizing type is most commonly known as a fundamentalist. The other knows many names, like chartist or noise trader, and they differ in trading rules over the different studies. Noise traders react on noise within the market and chartists are technical traders. Examples of chartist trading rules are momentum trading or in

⁷ Agent scan differ in many ways. For example in the way they form expectations, the information they have access to, their wealth, etc.

contrast the strategy of buying (selling) when prices have known a recent negative (positive) return, also known as contrarian trading⁸.

In the literature on agent based models which are based on a number of regimes with switching agents there are three major models (Chen, Chang and Du (2009)). The three models are the Kirman model (Kirman(1991, 1992)), the Lux model (Lux (1995, 1997, 1998)) and Brock-Hommes model (Brock and Hommes (1997, 1998)).

Kirman's model is based on two regimes of agents, namely fundamentalists and chartists. These two switch between each other based on a herding mechanism. Agents switch based on the ease in which they convert themselves and are converted by other agents. The second part of influence is depended on the fraction of agents within a group type. For instance, the more fundamentalists there are, the greater the odds a recent chartist is persuaded towards the other groups believes. Lux does also make use of a herding mechanism. The main difference between the switching mechanisms is the discrete way in which the fraction of agents switches between types in Kirman's model. This in opposition to the continuous way in which the agents switch in Lux's model. Apart from the difference in switching mechanism is Lux's model a hierarchal two type model. Next to the distinction between fundamentalist and chartist, there is also a distinction between optimistic and pessimistic chartists.

The youngest of the three major agent based models is the Adaptive Believe System (ABS) of Brock and Hommes(1997, 1998). In the market of the ABS there are a predefined number of believes which are not constraint to two or three different believes. The beliefs are assumed to be linear. The switching of agents happens based on a multinomial logit model. This mechanism is driven by the probability of gaining a profit in excess of risk free return. And so it puts weight on the recent believes about profitability. After all, agents most likely try to guess the behaviour of the market.

According to Chen, Chang and Du (2009), which survey the abounded studies on HAMs, the previously discusses two and three clustered type models are most popular. These are followed in popularity by many type models and the smallest fraction of studies use Autonomous Agent (AA) models. AA models do not pre-specify clusters of agents with approximately the same beliefs⁹. The programmed agents are able to learn and make predictions by evaluating movements in returns in the past. So without the necessity for pre-specification the agents form their own believes. Because these

⁸ The difference between a contrarian and a mean-reverting trading rule is long run equilibrium. The former reacts to the difference between the recent difference in price and takes an opposite position. The latter reacts to the difference between price and its long run equilibrium. Barber and Odean (2000) found this trading rule to approximate the average strategy of individual investors.

⁹ In models which make use of agent regimes (e.g. fundamentalist and chartist) the regimes can be seen as clusters of agents. Within these clusters agents can differ, but the reaction of and between the groups with fundamentally different believes are studied.

models are primarily used in combination with calibration, these models are not further discussed. An important finding in the overview of Chen, Chang and Du (2009) is that additional support of complex models in replicating stylized facts is found insignificant.

2.4 Empirical research

In contrast to the many HAM's which have been created and calibrated over the recent past. Little empirical research has been done in this field. The dynamic form of the HAM's brings complexity in testing the models on real world time-varying data. Still there have been a few attempts at indirect and direct estimation of the non-linear models on real financial data.

One of the first attempts at the task of empirical validation goes back to Shiller (1984). Shiller tested a model with investors who base their estimations on public information of dividends or earnings. These rational traders were called smart money traders. The other group of traders are known as ordinary traders. This group includes all traders which do not optimally make use of public information. According to Shiller, these bounded rational expectations can take many forms. Therefore there is no assumption made about the model of ordinary investors. Their effect is assumed to be zero. The dataset used consists of Standard and Poor's composite price index in the years 1900 till 1983. This total of years is split in clusters and the price is regressed on dividends-price and earnings-price ratios. The regressions result in a probability of social movements in demand.

Vigfusson (1997) and Ahrens and Reitz (2005) make use of Frankel and Froot's fundamentalist-chartist model (1990). These papers adjust the switching mechanism between the two groups as originally represented as a portfolio manager. They replace the mechanism with a Markov-switching regime. This results in periods where either the fundamentalist or the chartist regime dominates the market instead of a blend of the regimes formed by the manager. The results of the test on two different exchange rates indicate an outperformance of the model against their benchmarks.

Baak (1999) and Chavas (2000) both research short run supply within the US hog and beef market. By estimating optimal breeding models on cattle prices and filtering coefficients from these results. They find significant results concerning heterogeneity within the markets.

Winker and Gilli (2001) makes use of Kirman's model. They run multiple simulations and compare these with real financial world Deutsche Mark to US dollar exchange rates. This is done indirectly by minimizing the difference of kurtosis and ARCH-estimates in the real and simulated data.

Reitz en Westerhoff (2003) and Reitz en Westerhoff (2007) research respectively three currency rates against the US dollar and 36 commodities. The fundamentalist-chartist distinction is modeled. For the

switching mechanism they assume constant impact of the chartist and variable impact of the fundamentalist regime. The variable weight of fundamentalist regime is dependent on the gap between price and perceived fundamental price. They find cyclical motions in their researched markets.

Boswijk et al. (2007) rewrite the ABS model created by Brock and Hommes (1997, 1998). They use non-linear least squares to directly estimate the model with a mean reverting fundamental and a trend following chartist regime on their S&P500 data. The test results show statistically significant behavioural heterogeneity and variation over time between the two regimes. However, the parameters within the switching mechanism have not been found significant.

Chiarella et al. (2010) also tried to estimate changes in the S&P500 price index with an adjusted form of the ABS model. By making use of the maximum likelihood they investigate the influence of a possible fundamentalist, chartist and noise trading regime and switching behaviour of agents on price movements. By these constraining and benchmarking against the unconstrained model they also investigate the additional value of the constraint parts. They find statistically significant results with exception of the parameters imbedded in the switching model. This is in line with the previous discussed study of Boswijk et al. (2007).

De Jong et al. (2006, 2010) estimate a three type ABS model on data of eight different exchange markets within the European Monetary System. The first two regimes are the traditional fundamentalist and chartist regimes. The third additional regime is a chartist regime which, instead of relying on previous returns, forms its expectations through the difference between the short run and long run moving average of returns. The additional regime is known as the MA chartist. Next to the estimation they also try to forecast exchange rates over different horizons. By making use of Diebold and Mariano (1995) comparison test de Jong et al. demonstrate the outperformance of the HAM over a random walk.

De Jong et al. (2009) used the same procedure as in their previous research. But instead of the MA chartist they used in the FOREX market, they introduced an internationalist. The internationalist proxies the co-movement of fundamentals underlying markets. This contagion shifts over time through the switching mechanism of the ABS model. Approximately the same results concerning estimation and forecast ability were found on the Hang Seng and Bangkok S.E.T indices in the period surrounding the Asian crisis.

Empirical research on agent based models is still quite scarce. From the this relatively new form of research the most popular field of research seems to be the FOREX market and is followed by stock market index market. From the highlighted studies in this paper Boswijk et al. (2007), Chiarella et al. (2010) and De Jong et al. (2006, 2009, 2010) are among the few which estimate coefficients directly without replacing the switching mechanism. The studies of De Jong et al. (2006, 2009, 2010) go one step beyond in trying to test the forecast ability of their models. Overall the results from the empirical studies support the existence of heterogeneity within different markets.

3 The model

In this paper an adjusted form of the ABS of Brock and Hommes(1997, 1998) will be used. A reason for this decision can be found in the use of this model in past studies like Boswijk et al. (2007), Chiarella et al. (2010) and De Jong et al. (2006, 2009, 2010) (paragraph 2.4). The ABS has proven to be compatible with real financial data and the robustness of the found results can be benchmarked against the previous study results. The portfolio forming rational is another reason for the use of an adapted form of the ABS. The weight that is put on a trading rule is dependent on its performance in the past. Selection based on past profitability makes more sense than for instance the size of the group like in the switching mechanism of the Kirman (Kirman(1991, 1992)) and the Lux model (Lux (1995, 1997, 1998)). The adjusted form of ABS used by the study of Chiarella et al. (2010) will be tested in this thesis. Reasons for this choice are the addition of noise traders within the model, the relatively more realistic market micro structure and the compatibility with weekly frequency data¹⁰. Noise traders are a theoretically grounded group which is supposed to create limits to arbitrage (paragraph 2.2) and their possible existence within the market are found important to investigate. The model incorporates adaption on the ABS model made by Chiarella and He (2003). The originally proposed Walrasian scenario for arriving at the market clearing price (Brock and Hommes(1997, 1998)) is replaced by one with a market maker. In filling in different kind of beliefs of agents Chiarella et al. (2010) are followed in their interpretation of a fundamentalist, chartist and noise trader trading regime. Fundamentalist are assumed to expect reversion towards the fundamental price. The form of the chartist function, which normally has the form of a first order auto regression (AR(1)), is supposed to follow a long run moving average (MA). This MA is given by a Geometric Decay Process (GDP). The noise traders act on the noise in the market as proxied by the variance. Agents are categorised in regimes based on their believes. Although the model's form is still stylized in comparison with the real financial world, the adoptions make the ABS more realistic.

3.1 *The market and the market maker*

In the ABS model agents have the possibility to invest their money in either a risk free asset or one which carries risk. The risk free asset is assumed to be perfectly elastic in supply. Meaning the variation in demand is offset by changes in supply. This in a way in which the ratio demand-supply remains stable. Because of this property, the price of the risk free asset is not influenced by demand and supply changes. The asset is also assumed to pay out a fixed rate of return denoted r in which makes the gross return R which equals $1 + r$ plus the risk free return r . The risky asset in contrast pays an unknown amount of dividend. The time varying stochastic dividend process at time t of the risky asset is denoted y_t . The price in exclusion of dividend of the risky asset is denoted p_t . Agent type h 's demand for the risky asset is depended on the return in excess of the risk-free rate, the fluctuations in

¹⁰ The frequency argumentation will be further explained in the data and methodology chapter 4.

excess return as captured by the perceived variance at time t ($V_{h,t}$) and the risk aversion concerning these fluctuations. The risk aversion parameter η is assumed to be constant and equal over all the type of agents. Chiarella and He (2003) show the differences in risk aversion are a potential cause of variation between agent types. For matter of testing the previously stated assumption is made following the studies of Boswijk et al. (2007) and Chiarella et al. (2010). Given this setup, the demand z for the risky asset of agent type h at time t is given by:

$$(1) \quad z_{h,t} = \frac{E_{h,t}[p_{t+1} + y_{t+1} - Rp_t]}{\eta V_{h,t}[p_{t+1} + y_{t+1} - Rp_t]} = \frac{E_{h,t}[p_{t+1} + y_{t+1} - Rp_t]}{\eta \sigma^2}$$

Believes of type h agents at time t about future return in dividend and price change in excess of the risk free return is denoted $E_{h,t}$. These conditional expectations are compared with the perceived variance $V_{h,t}$. For analytical tractability the conditional variance, as the previously discussed risk aversion parameter, is assumed to be constant and equal for all traders¹¹ so $V_{ht} = \sigma^2$. This simplification results in the last formulation. Agents are assumed to maximize expected return against risk believes captured by variance and risk aversion. These traders handle like myopic mean variance maximizes. The supply of outside risky assets per investor is denoted z_s . In totality there are H different types of traders within the market. Each regime has its fraction n at a point in time. These fractions take a value between $0 < n_{h,t} < 1$ and the sum of all fractions has to equal 1¹². The equilibrium between demand and supply becomes:

$$(2) \quad z_e = \sum_{h=1}^H n_{h,t} \frac{E_{h,t}[p_{t+1} + y_{t+1} - Rp_t]}{\eta \sigma^2}$$

Brock en Hommes (1998) and Chiarella and He (2003) assume constant net supply of zero. This means the net long and short positions within the market offset each other and no new risky assets have to be issued or retracted. The excess demand or supply will cause the market maker to take an adjust prices and take an opposite position to clear the market. In the case of homogenous rational agents ($H=f$ and $n_f = 1$) there will be no excess supply or demand ($z_e=0$). The price will equal the fundamental price and becomes:

$$(3) \quad P_t^* = \sum_{k=1}^{\infty} \frac{E_t[p_{t+k} + y_{t+k}]}{R^k} = \sum_{k=1}^{\infty} \frac{E_t[y_{t+k}]}{R^k}$$

¹¹ The release of the homogenous constant variance assumption is tested by Gaunersdorfer (2000). He finds few differences in the details, but concludes with the similarity of the global qualitative features of the model.

¹² We assume the market is only populated by the specified heterogeneous type of agents. As a result the sum of all fractions have to equal to the total of 1.

Because the future price is a function of its discounted future prices and dividends and so on. The price is ultimately only dependent on the sum of all discounted future dividends. Brock and Hommes focus on the case in which the time varying stochastic dividend process is independent and identical distributed (IID). The distribution assumption makes the best guess of future dividends its mean value. In the empirical studies stated in the introduction of this chapter this assumption is altered by taking into account the growth of dividend. The dividend expectations becomes:

$$(4) \quad E_t[y_{t+1}] = (1 + g_t)y_t$$

In which g_t is the dividend growth estimated at time t and is assumed to be updated as soon as new information becomes available. It is common in empirical studies which make use of a form of the ABS to estimate the fundamental price using the Gordon growth model (1962). This growth model is a combination of formula (3) and (4) and has the form:

$$(5) \quad P_t^* = \frac{1+g_t}{r_t-g_t} Y_t$$

The fundamental price is a benchmark in the ABS model. It will only hold if there is one type of agent, the agents are rational and it is commonly known every agent is rational. The ABS assumes all agents have the same expectations about future dividends meaning $E_{ht}[y_{t+1}] = E_t[y_{t+1}]$. So the mean expected fundamental price is equal over all types of agents. Agents form their expectations with respect to deviations from this price. These deviations are of the form:

$$(6) \quad x_t = p_t - p_t^*$$

Taking into account the forecasting error of the fundamental price over time(δ) the excess return of the price deviations at time t is:

$$(7) \quad R_t = x_t - R x_{t-1} + \delta_t \quad \text{where} \quad \delta_t = p_{t+1}^* + y_{t+1} - E_t[p_{t+1}^* + y_{t+1}]$$

The excess return is equal to the return in excess of the risk free rate plus the forecasting error. Because of the previously stated homogenous expectations concerning the dividend process, the best guess of the forecasting error is equal to zero. Agents are able to calculate the fundamental price, however they do not believe the real world price is always equal to fundamentals. The trading rules which defer over agent types are assumed to be linear and for every time t of the form:

$$(8) \quad E_{h,t}[p_t + y_{t+1}] = E_t[p_{t+1}^* + y_{t+1}] + f_h(x_{t-1}, \dots, x_{t-k})$$

The f in this function symbolizes the expectations of agent type h concerning the deviations from the fundamental price. The agents base their expectations on a information set with k lags. The following paragraph will fill in the different groups of agents and their trading rules. Because of the similar form in which different agents act, the dynamics of the market maker can be described in deviations from the fundamental price (x) and excess demand (z_e). The market maker takes an opposite position and adjust prices in the coming period to offset this position. The speed in which the price adjustment takes place is denoted μ . The function of the market maker becomes:

$$(9) \quad x_{t+1} = x_t + \mu z_e$$

3.2 *Different groups of agents*

To test if heterogeneous believes can explain movements in price the agents are categorized based on their trading rules. As stated the groups all have trading rules of the form (8). This thesis follows the study of Chiarella et al. (2010) in testing three groups of participant types, namely fundamentalist, chartists and noise traders. The fundamentalist trading rule focuses solely on the difference between the real and fundamental price. Their trading rule is of the form:

$$(10) \quad E_{f,t}(x_{t+1}) = x_t - \alpha x_t = (1 - \alpha)x_t$$

It is expected that the fundamentalist believes in the return towards the fundamentals. If this would be the case then $0 < \alpha \leq 1$. The higher the α within these borders, the higher the expected speed of return. In the case of $\alpha < 0$ the fundamentalist expects the market to drive prices farther from its fundamental value. If $1 < \alpha$ the fundamentalist expects overshooting, a correction towards and beyond the fundamental price. Combining formula (7) and (10) results in the expected return of the fundamentalist trading rule:

$$(11) \quad E_{f,t}(R_{t+1}) = (1 - R - \alpha)x_t$$

The second group is the chartist group. Chartists are assumed to be technical traders. They compare the short run with the long run moving average and form their expectations on the difference. The study of Zhu and Zhou (2009) provides evidence for the usefulness of this momentum trading strategy. As stated by Chiarella et al. (2010) it is hard and trivial to estimate and validate a lag length for testing this rule in practice. As a solution the chartist regime is assumed to form its expectations based on a geometric decay process (GDP) in the form:

$$(12) \quad E_{c,t}(x_{t+1}) = x_t + d(x_t - \tau_t) \quad \text{where} \quad \tau_t = \omega \tau_{t-1} + (1 - \omega)x_{t-1}$$

The τ is the geometric decay function which can also be seen as the geometric moving average. The ω is the weight which is put on past observations. It should have a value between $0 < \omega < 1$ in which a higher value equals more weight on past price observations. The d represents the expectations based on the past deviations. If $d > 0$ then the technical rule implies a destabilizing effect away from the long run moving average. If $-1 \leq d < 0$ then the chartist strategy expects the deviation to move towards its long run moving average. As a last option $d < -1$ which implies overshooting in the same sense as the fundamentalist rule can overshoot the fundamental price. A combination of (7) and (12) gives the expected return of the chartist trader as:

$$(13) \quad E_{c,t}(R_{t+1}) = (1 - R)x_t + d(x_t - \tau_t)$$

The demand for the risky asset of the fundamentalist and chartist group can be obtained by putting expected returns (11) and (13) in function (1). The demand functions of the fundamentalist (z_f) and chartist (z_c) group at time t becomes:

$$(14) \quad z_{f,t} = \frac{(1-R-\alpha)x_t}{\eta\sigma^2}$$

and

$$(15) \quad z_{c,t} = \frac{(1-R)x_t + d(x_t - \tau_t)}{\eta\sigma^2}$$

The last group of traders are noise traders. They trade based on signals or “noise” and not on risk return considerations like the fundamentalist and chartist group. Their demand function is of the form:

$$(16) \quad z_{n,t} = \sqrt{S_t}\varepsilon_t \quad \text{where} \quad \varepsilon_t \sim (0,1)$$

The parameter S is an approximation of the market sentiment. Noise traders can create risk as discussed in chapter 2.2. This risk they create is volatility and this volatility effects prices¹³. Because of the influence on volatility the market sentiment can be captured by a GARCH process in the form:

$$(17) \quad S_t = \phi_1 + \phi_2 S_{t-1} + \phi_3 \varepsilon_{t-1}^2$$

¹³ Chiarella et al. (2010) points out that because of the relation between the created systematic risk which influences prices, the noise signal can be seen as sentiment.

In which ϕ_1 is a constant, ϕ_2 a memory parameter and ϕ_3 captures the sensitivity of the lagged squared residuals. The constant ϕ_1 is a combination of the long run variance and it's weight. The parameters ϕ_2 and ϕ_3 and the weight of long run variance have to add up to one.

3.3 Switching between groups

The remaining part of the model is the switching mechanism between groups. Agents are not assumed to blindly and conservatively follow their trading rules. They evaluate their performance and benchmark it against other trading rules and make choices accordantly. For this reason a switching mechanism is build into the ABS model. However, noise traders are assumed to have a constant fraction within the market. These trades do not act on trading rules but react on noise and are not likely to evaluate their expectation forming process to switch towards a trading rule and vice versa. The agents within trading on the remaining fundamentalist and chartist regimes are assumed to switch between these groups. The sum of all fractions n have to add up to 1 in which the noise trader group has a constant fraction. The relative difference between the fundamentalist and the chartist group (m) at time t can be written as:

$$(18) \quad m_t = \frac{n_{f,t} - n_{c,t}}{n_{f,t} + n_{c,t}} = \frac{n_{f,t} - n_{c,t}}{1 - n_n}$$

The relative weight m can fluctuate between $[-1,1]$ with -1 as a domination of the chartist and 1 as a domination of the fundamentalist in the remainder of the market. Adjusting the market maker function (9) with the relative weight function (18), the market maker function becomes:

$$(19) \quad x_{t+1} = x_t + \frac{\mu}{2} [(1 - n_n) ((1 + m_t)z_{f,t} + (1 - m_t)z_{c,t}) + 2n_n z_{n,t}]$$

The fundamentalists and chartists evaluate their performance and consider switching their trading rules accordantly. This performance is assumed to be measured by profitability of their trading rules. The profitability equals the ex-post excess return times the amount of assets they demanded in the past and so:

$$(20) \quad \pi_{h,t} = (x_t - Rx_{t-1} + \delta_t)z_{h,t-1}$$

This performance can be used in the switching model of the ABS model. The complete switching model takes possible cost into account. As both the trading rules are quite simple and do not require intensive or costly research these costs are assumed to be nil. Because the switching will only occur

between two groups the form of switching mechanism can be written in a hyperbolic tangent form. This adjustment as in the research of Chiarella et al. (2010). The mechanism becomes:

$$(21) \quad m_t = \tanh\left(\frac{\beta}{2} [\pi_{f,t} - \pi_{c,t}]\right) = \tanh\left(\frac{\beta}{2} [x_t - Rx_{t-1} + \delta_t][z_{f,t} - z_{c,t}]\right)$$

The β in this function represents the speed of adjustment as a reaction to differences in performance and is also known as the intensity of choice. The higher the β , the higher the speed of adjustment. The extremes are 0 in the case of no switching and a uniform distribution and extreme switching when β goes to infinity.

3.4 *The adjusted Adaptive Believe System with Market Maker*

The complete model to be studied consists of a fundamentalist, chartist and noise trading group of agents and a market maker. Fundamentalists are expected to believe the prices return to their fundamental value. Chartists are technical traders which compare prices with their long-run moving averages and form expectations on these differences. The fundamentalist and chartist group are expected to switch between their regimes based on considerations concerning past performance in the form of excess return. The last group of traders consists of noise traders which act on noise signals and are not expected to consider other trading rules. The market maker takes care of excess demand or supply by taking an opposite position and adjusting future prices.

The model to be studied can be obtained by filling in the demand functions (14), (15) and (16) into the market maker function (19) and the switching mechanism (21). The adjusted form of the ABS with adjustments made by Chiarella and He (2003) and Chiarella et al. (2010) becomes:

$$(22) \quad x_{t+1} - x_t = \frac{\mu(1-n_n)}{2\eta\sigma^2} [2(1-R)x_t - (1+m_t)\alpha x_t + (1-m_t)d(x_t - \tau_t)] \\ + n_n\mu\sqrt{S_t}\varepsilon_t$$

$$(23) \quad \tau_t = \omega\tau_{t-1} + (1-\omega)x_t$$

$$(24) \quad S_t = \phi_1 + \phi_2 S_{t-1} + \phi_3 \varepsilon_{t-1}^2$$

$$(25) \quad m_t = \tanh\left(\frac{\beta}{2\eta\sigma^2} [x_t - Rx_{t-1} + \delta_t][-\alpha x_t - d(x_t - \tau_t)]\right)$$

4 Data and Methodology

To answer the question, if movements in European stock indices can be explained by heterogeneity of participating agents, data was collected. For the chosen adjusted form of the ABS described in chapter 3 a fundamental price has to be calculated. This thesis follows Chiarella et al. (2010) in their choice of testing data with weekly frequency. Paragraph 4.1 describes the considerations concerning the fundamental price. Thereafter the data collection is described in paragraph 4.2 and paragraph 0 concludes with adjustments on the model concerning the compatibility for testing it on the data.

4.1 The Fundamental price

To calculate the fundamental price (P^*) de Jong et al. (2009), Boswijk et al. (2007) and Chiarella et al. (2010) are followed in using the Gordon growth model (1962). This growth model is the function (5) described in chapter 3, namely:

$$(26) \quad P_t^* = \frac{1+g_t}{r_t-g_t} Y_t$$

In which r is the discount factor and g the growth rate of dividend. The fundamental price at time t can be calculated by multiplying the growth and discount part of the equation with dividend at time t . According to Fama and French(2002) the discount rate, or average stock return, consists of the average dividend yield, $E(Y_{t+1}/P_{t+1})$, and the average capital gain, $E((P_{t+1}-P_t)/P_t)$. The latter is equal to the growth of dividend within the Gordon model. With this given, the model can be rewritten as:

$$(27) \quad P_t^* = \frac{1+g_t}{E\left(\frac{Y_{t+1}}{P_{t+1}}\right)} Y_t$$

A final adjustment proposed by the de Jong et al. (2009) and Chiarella et al. (2010) is the usage of earnings instead of dividend. This variable is relatively less influenced by management choices and is still co-integrated with price¹⁴. The earnings of a stock market index is the accumulation of the earnings from different companies within the index. Earnings are usually announced quarterly in contrast to the frequently updated prices. This relatively stable earnings are assumed not form troubles for the analysis. Boswijk et al. (2007) test their model with the 10 year moving average of their earnings data. This makes these earnings even more stable than the earnings data used in this thesis. The studies of Jong et al. (2009) and Chiarella et al. (2010) also use quarterly updated earnings in their calculation of the fundamental price.

¹⁴ This last argument makes earnings a potential substitute (Fama and French (2002)).

4.2 Data on European stock market indices

The data collected comes from DataStream. To make the compatible with the main question of this thesis, the testing model and with the Gordon Growth model restrictions have to be formed. This thesis makes use of earnings which are pre-calculated by DataStream as the Stock indices do not earn earnings themselves. The data has to:

- Be an European Stock index
- Be of weekly frequency
- Have prices and pre-calculated earnings accessible through DataStream
- Be listed on the London Stock Exchange

The requirement of the listing on the London Stock Exchange (LSE) comes from the incorporation of a market maker within the HAM. The LSE makes use of market makers making the traded indices compatible with the model. The remaining indices for study are the AEX, BEL 20, CAC 40, DAX 30 and FTSE 100 indices (See Table 8:1). These indices are studied from their period of foundation until the first week of September 2011. This includes movements in a period close to the total life of the indices. This sample period is chosen because this thesis wants to study price movements of European indices in general. By testing over different periods and indices the robustness of the results can be examined.

Fundamental prices of the indices are calculated with the Gordon Growth model discussed in the previous paragraph. The growth and earnings-price ratio are updated every week further into the sample. Using all information until the date of calculation. The price, fundamental price and their difference per index are graphed to investigate and compare patterns within and between them (see Figure 8:1). The price movements of the indices all show a steady grow with two major drops. One between the years 2000 and 2002 which is mainly caused by the burst of the dot-com bubble. The other is around 2007 which indicates the beginning of the financial crisis. Overall the fundamental prices also show a similar line of movement between the different indices. A steady grow until the credit crisis of 2007 in which the price drops down. In the years of the creation of the dot-com bubble the fundamental price remains quite stable as a bubble is created on overvaluation and not based on performance. The credit crisis was mainly caused by a lack of understanding a few financial instruments. This lack caused an underestimation of the risk incorporated within these instruments. The main difference this build up boosted performance of companies (mainly financial) which influences future expectations based on performance until the burst.

Table 4:1 Descriptive Statistics

	AEX				BEL 20			
	P	P*	X	ΔX	P	P*	X	ΔX
Mean	285.1395	255.3158	29.98324	-0.089397	2389.119	2569.760	-179.7799	0.016577
Median	257.7060	193.5079	20.95820	0.277497	2445.339	2492.705	-46.13808	2.112285
Maximum	695.1940	752.7614	391.5434	96.65677	4710.552	5404.338	1407.141	554.7959
Minimum	46.48600	47.09506	-470.1661	-54.99649	956.4780	880.4427	-2453.558	-566.6541
Std. Dev.	173.4154	183.9267	131.5347	10.75815	928.9004	1182.884	659.1948	81.27507
Skewness	0.503962	0.971226	-0.173218	0.649116	0.368568	0.326099	-0.832376	-0.158080
Kurtosis	2.083030	2.987361	5.168924	15.39376	2.344841	2.168620	4.227888	15.10472
Observations	1497	1496	1496	1495	1132	1131	1131	1130
	CAC 40				DAX 30			
	P	P*	X	ΔX	P	P*	X	ΔX
Mean	3407.980	3243.406	164.5745	-1.549197	3288.029	3224.983	63.04561	-2.165180
Median	3390.796	3109.816	107.6953	2.906455	2496.232	2364.575	105.9549	4.403910
Maximum	6770.558	6518.085	3291.211	509.3321	8047.756	9611.367	3433.281	858.5151
Minimum	1490.532	1341.581	-2907.891	-707.6215	470.1820	418.7655	-3673.630	-994.8135
Std. Dev.	1382.172	1493.650	928.2085	106.3022	2219.245	2461.048	1068.032	126.2790
Skewness	0.414876	0.532484	0.188459	-0.315170	0.456973	0.802713	0.191458	-1.104800
Kurtosis	2.105209	2.025764	4.361118	8.310700	1.840184	2.554111	3.637630	12.11148
Observations	1184	1184	1184	1184	1601	1601	1601	1601
	FTSE 100							
	P	P*	X	ΔX				
Mean	5076.257	6069.860	-993.6033	-5.382559				
Median	5206.722	5288.811	-752.4167	-1.038817				
Maximum	6861.866	10784.91	2464.556	1684.178				
Minimum	2922.160	3685.224	-5592.236	-1102.927				
Std. Dev.	1005.439	1958.828	1767.219	159.3741				
Skewness	-0.321947	0.800820	-0.270406	0.814749				
Kurtosis	2.010488	2.164217	2.522691	24.95354				
Observations	899	899	899	899				

Notes: Descriptive statistics of the price (P), fundamental price (P*), the difference between the price and its fundamental price (X) and the one period change of this difference (ΔX).

The BEL20, CAC40 and DAX30 indices seem to have prices relatively close to their fundamental value. The prices of the AEX and FTSE100 know periods of big difference when compared with its fundamental value. The biggest difference in data statistics compared to the S&P500 statistics of Chiarella, et al. (2010) is the higher standard deviation of the fundamental price in comparison with the real price. This possibly thanks to the relatively shorter time period with high earning fluctuations. Overall the price, its fundamental value and the difference between them seem not to be stationary.

The non stationary characteristics of the previously discussed parameters should not form a problem as long as the depended variable of the test is. To get an indication of the stationary of the depended variable of the model an Augmented Dickey-Fuller test (ADF) is performed. All the indices reject the null hypothesis which indicates insignificant probability of a unit root (see Table 8:2). There is no reason to assume non stationary distribution.

4.3 Methodology

Not all the parameters of the model, consisting of the functions (22) till (25), can directly be estimated. The price adjustment speed of the market maker (μ) in the model is only found in combination with the variance (σ^2), risk aversion and the fraction of fundamentalists and chartists in the market ($1 - n_n$). This is also the case with the intensity of choice (β) with exception of the fundamentalist and chartist fraction. To solve this problem a few simplifying adjustments have to be made. A simplifying assumption is a risk free rate of zero ($r=0$). As pointed out by Chiarella et al. (2010) this is a safe assumption to be made. Thanks to the high frequency of the data the real risk free rate is very small. A second adjustment concerns the parameters α and d which will be estimated as impact factors. A combination of their individual impact, risk aversion and variance in combination with risk. These impact factors will be estimated in combination with the price adjustment speed (μ) and intensity of choice (β) because of their linear relation with these coefficients. The last adjustment is to set both noise trader fraction (n_n) and the remaining fraction ($1 - n_n$) equal to one. It are scaling factors which can be dropped without loss of generality (see Chiarella et al. (2010)). The adjusted model including intercept reads:

$$(28) \quad x_{t+1} - x_t = c - [-(1 + m_t)\alpha^*x_t + (1 - m_t)d^*(x_t - \tau_t)] + \sqrt{S_t}\varepsilon_t$$

$$(29) \quad \tau_t = \omega\tau_{t-1} + (1 - \omega)x_t$$

$$(30) \quad S_t = \phi_1 + \phi_2 S_{t-1} + \phi_3 \varepsilon_{t-1}^2$$

$$(31) \quad m_t = \tanh[(x_t - x_{t-1})(-\alpha^{**}x_t - d^{**}(x_t - \tau_t))]$$

In which α^* and d^* are respectively α and d multiplied by μ and α^{**} and d^{**} are respectively α and d multiplied by β . To get starting values for the complete model the model is estimated with the price adjustment speed (μ) combined with the fundamentalist and chartist parameters and without a switching mechanism ($m_t = 0$). Thereafter the complete model will be estimated. To retrieve the price adjustment speed and the intensity of choice Chiarella et al. (2010) are followed in minimizing the loss function¹⁵:

$$(32) \quad \mathbb{Z} = \frac{|\alpha^* - \mu\alpha|}{|\alpha^* + \mu\alpha|} + \frac{|d^* - \mu d|}{|d^* + \mu d|} + \frac{|\alpha^{**} - \beta\alpha|}{|\alpha^{**} + \beta\alpha|} + \frac{|d^{**} - \beta d|}{|d^{**} + \beta d|}$$

¹⁵ The values of the parameters are estimates with standard errors and a chance of being a different value. That is why a minimum loss optimization has to be preformed. Starting values are $\mu = 1$, $\beta = \alpha^{**}/\alpha^*$ and α and d are their estimated values in the model with market maker and switching restrictions.

5 Results

In this chapter the results of the test of the HAM on the data and based on the methodology described in chapter 4 will be discussed. In paragraph 5.1 the results concerning the full model will be discussed. Thereafter the significance of the different types of agents will be presented in paragraph 0. The switching dynamics and the market maker will be discussed in paragraph 0. The final paragraph of this chapter will conclude with an description of the switching characteristics of the fundamentalist and chartist regime.

5.1 *An estimation of the full model*

The results of the test of the main model can be found in Table 5:1. All the coefficients of the model, with exception of the switching parameters, are significant. Fundamentalist, chartist and noise traders as they are described in chapter 3 seem to be active in trading the European indices. The fundamentalist parameter is positive and of the same magnitude as in the previous study of Chiarella et al. (2010). Which is quite low thanks to the high frequency of the data. When allowed to switch the fundamentalist regime seems to expect prices to return to their fundamental value in a period of about 45 weeks for the AEX, 35 weeks for the BEL20, 20 for the CAC40, 30 for the DAX30 and 45 weeks for the FTSE100. The fundamentalist in the restricted model seem to believe the prices will return to their fundamental value in a period of about 530 weeks for the AEX, 85 weeks for the BEL20, 80 for the CAC40, 130 for the DAX30 and 390 weeks for the FTSE100¹⁶. The fundamental price reversion expectations of fundamentalists are also the result of the studies of Boswijk et al. (2007) and De Jong et al. (2009). De Jong et al. (2009) find the fundamentalist regime expects deviations in the Bangkok SET and Hang Sen stock index to revert in less than a year (<52 weeks). This is faster than every expected reversion found in the restricted test on the indices within the sample. The results of the unrestricted model give comparable revision speeds. The study of Chiarella et al. (2010) finds an expected 250 weeks to revert which is more in line with the found results of the restricted model.

The chartist parameters are also highly significant. The usage of past deviations from the fundamental price in the calculations of the chartist as represented by the ω s are high suggesting much use of this past information. The parameter d is small and positive suggesting a chartist expectation of a long run growing trend in deviations from the fundamental price. This main observation considering the chartist regime is the same result found in the study of Chiarella et al. (2010). However the use of past information is higher and the trend growth lower than the these results. Their results of a test on a sub period between 1995-2009 also shows a lower and more comparable value for parameter ω . They assign this lower memory to necessity in a period with higher volatility. In a volatile market with big changes you cannot always rely on information to far back. The sample periods in this study are

¹⁶ Calculated by dividing 1 through the value of the fundamentalist parameter.

around this more volatile period. Boswijk et al. (2007) find significant results for a short run orientated chartist regime. De Jong et al. (2009) investigate a chartist regime which discriminates between positive and negative past movements. They find chartists have contrarian expectations when it comes to positive movements and momentum expectations when it comes to negative movements in the price of Bangkok SET stock index. In contrast they only find chartists in the Hang Sen market to have contrarian expectations of negative price movements.

The switching of the fundamentalist and chartist regime is insignificant which is normal in empirical studies on forms of the ABS. The importance of switching between regimes is found when restricting the parameter β to zero and comparing the likelihoods of the unrestricted and the restricted form (Teräsvirta 1994). The significance of the restricted parameters are calculated by the function:

$$(33) \quad LLR = -2(L_u - L_r) \sim \chi^2(m)$$

In which the L is the likelihood of the unrestricted (u) and restricted (r) model and m are the number of restrictions. The importance of the restricted parameters is significant at all the different stock indices. However there are contrast in the results in comparison with the study of Chiarella, et al. (2010). The first difference in results can be found in the results of the restricted form of the model (B). When leaving out the switching model the parameter d almost doubles and the weight of previous data used by the chartist becomes approximately zero as they become insignificant. This suggest that without switching between the regimes the chartist follow an simple AR(1) process, catching short run trends. This could be an indication of a combination of short run trend chasing chartist and a long run momentum trading chartist regime which are both caught by the chartist part of the full model¹⁷. As momentum trading is a long run strategy the trading frequency of these traders should be lower in comparison with other discussed trading strategies. Thanks to this lower trading frequency the momentum trader will only be caught when there is a possibility to change to this regime at the moments when the traders do trade. This study suggest a possible omitted variable bias in parameters and in particular the parameters of the chartist regime¹⁸. The results of De Jong et al. (2009) also show a relatively big shift in their chartist parameters values when comparing their model with and without switching.

A second difference in results in comparison with the study of Chiarella, et al. (2010) can be found in the values of the coefficients of the noise traders. As discussed in chapter 3 the noise traders are approximated with a GARCH model. The previous study finds values which are comparable with a

¹⁷ The suggestion of a momentum trading strategy is because of the lower value of d when this suggested strategy is caught. Meaning a possible negative and so mean reverting strategy.

¹⁸ The possible short run chartist regime should be correlated with the remaining independent variables as it is a combination of x and its 1 period lag.

Table 5:1 Estimation of the full model with and without switching

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
c	0.546013*** (0.117693)	0.183512 (0.112122)	2.300789** (1.126350)	0.865532** (1.161265)	6.969096*** (1.742301)	1.185022 (1.939734)	1.217068* (0.682649)	0.887919 (0.877851)	-17.97271*** (3.080484)	-4.254076 (3.726957)
α^*	0.022917*** (0.002099)	0.001890 (0.001613)	0.030658*** (0.003106)	0.011517*** (0.002722)	0.047266*** (0.002582)	0.012662*** (0.002918)	0.033205*** (0.003645)	0.007781*** (0.002874)	0.022738*** (0.001576)	0.002563 (0.002635)
d^*	0.114929*** (0.012724)	0.211810*** (0.028207)	0.168931*** (0.017346)	0.301878*** (0.031944)	0.175764*** (0.020811)	0.301991*** (0.029910)	0.132207*** (0.016916)	0.262140*** (0.022264)	0.163249*** (0.014690)	0.222546*** (0.034510)
ω	0.864820*** (0.024931)	0.146469 (0.121308)	0.782671*** (0.027519)	-0.033534 (0.116620)	0.666617*** (0.047255)	-0.067048 (0.108036)	0.904477*** (0.018292)	-0.112661 (0.103637)	0.603913*** (0.055849)	0.057883 (0.170957)
α^{**}	0.079564 (0.051308)		0.000576 (0.000393)		0.000404* (0.000210)		0.013477 (0.014178)		9.40E-05*** (1.84E-05)	
d^{**}	0.167719 (0.115294)		0.002408* (0.001437)		0.001731* (0.000936)		0.121252 (0.126650)		0.000766*** (0.000154)	
Φ_1	1.035415*** (0.143864)	0.315127*** (0.040918)	54.14882*** (9.581530)	42.57295*** (8.287054)	71.41614*** (17.52311)	45.16383*** (12.82101)	12.95169** (5.614154)	1.780271*** (0.296930)	51.92421*** (18.46752)	-1.415071 (17.20342)
Φ_2	0.636652*** (0.038328)	0.844545*** (0.009311)	0.803457*** (0.016458)	0.841103*** (0.005655)	0.807321*** (0.030383)	0.892859*** (0.010351)	0.624192*** (0.079253)	0.964404*** (0.002516)	0.936222*** (0.008179)	0.950531*** (0.005845)
Φ_3	0.290045*** (0.029430)	0.182632*** (0.012478)	0.236563*** (0.022294)	0.208352*** (0.009415)	0.151719*** (0.025819)	0.113712*** (0.012049)	0.344069*** (0.048722)	0.042364*** (0.003486)	0.064318*** (0.008999)	0.059700*** (0.007865)
Logl	-4724.968	-4853.451	-6271.508	-6289.383	-7025.523	-7180.323	-9078.177	-9277.151	-5757.041	-5877.186
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR		256.967***		35.749***		309.599***		397.349***		240.291***

Notes: The estimation of the full model containing fundamentalist (α), chartist (d and ω) and noise traders (ϕ) with (A) and without (B) switching. The restricted model estimation (B) restricts the market maker parameter at the value 1 and the switching parameter at 0. The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients. The *, ** and *** are significance at a 10%, 5% and 1% level.

GARCH estimation on real prices. In contrast this study finds less comparable values with as biggest difference that the accumulation of Φ_2 and Φ_3 which is greater than 1 in both the restricted and unrestricted model. This violates an important assumption of the GARCH model because the variance does not stabilize and result in no long run average variance. This could be caused by the suggested omitted variable bias and/or the difference in the variance of the prices in comparison with the variance of the fundamental price which is pointed out in chapter 4.

5.2 The strategies of different of agents types

To investigate the importance and existence of the different trader types the full model will be tested against different restrictions. The first restriction comes forth out of the findings in previous paragraph. The usage of previous data in the calculation of chartists (ω) will be restricted to 0 and in comparison with the full model. By comparing the likelihood of the restricted and unrestricted model a comparison is made between long run and short run (AR(1)) chartists¹⁹. The results of this test can be found in Table 5:2. The results are concerning the two types of chartists mixed. The restricted model seems to outperform the unrestricted model when tested on the AEX, BEL20 and the FTSE100 index. In the case of the CAC40 and DAX30 index the restriction of the ω is significant meaning the inclusion of the variable is of significant value within the model.

The noise traders still violate the GARCH assumption. For this theoretical reason the noise trader approximation will be converted to an IGARCH function, meaning restricting the constant Φ_1 to 0 and restricting the accumulation of the remaining noise trader parameters to 1. This takes out the possibility of a long run variance, but makes sure this variance is nonnegative²⁰. When the possible long run chartist is put against the short run chartist in this restricted model the results are in favour of the long run chartist with exception of the FTSE100 (see Table 5:3). Also note that the noise trading regime is far more stable and has values which are expected when performing a IGARCH on price data. In comparison with Chiarella, et al. (2010) the noise trading regime estimation lacks a long run variance. But their significant coefficient shows they do have influence on the variance and so they do create risk like described by behavioural finance theory (see chapter 2.2). When the long run and short run chartist are compared in a model without a possibility to switch the results are in favour of the short run chartists in almost all cases as can be seen in Table 5:4. The results of Table 5:3 in comparison with Table 5:4 puts weight on the suggestion that possible momentum trading has a lower trading frequency in comparison with other discussed trading strategies. The possibility to switch makes the model compatible to catch these at a lower frequency traders.

¹⁹ Addition of both a long run and short run chartist requires rewriting of the model. Because of the choice to investigate heterogeneity within European indices with the model of Chiarella, et al. (2010) the rewriting of the model is beyond the scope of this thesis and is left for future research.

²⁰ Which is impossible as is variance the standard deviation to the power of two.

Table 5:2 Estimation of long run versus short run chartists

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(A)	(C)	(A)	(C)	(A)	(C)	(A)	(C)	(A)	(C)
c	0.546013*** (0.117693)	1.128255*** (0.094878)	2.300789** (1.126350)	1.826762 (1.413978)	6.969096*** (1.742301)	9.022070*** (1.933771)	2.706820*** (0.772745)	2.428524*** (0.527151)	-17.97271*** (3.080484)	-23.8882*** (2.967907)
α^*	0.022917*** (0.002099)	0.035678*** (0.001561)	0.030658*** (0.003106)	0.040768*** (0.005356)	0.047266*** (0.002582)	0.049469*** (0.003405)	0.033549*** (0.004142)	0.036738*** (0.005325)	0.022738*** (0.001576)	0.027710*** (0.001360)
d*	0.114929*** (0.012724)	0.198790*** (0.031823)	0.168931*** (0.017346)	0.261933*** (0.040139)	0.175764*** (0.020811)	0.229094*** (0.032139)	0.134448*** (0.014326)	0.372349*** (0.049539)	0.163249*** (0.014690)	0.167878*** (0.018404)
ω	0.864820*** (0.024931)		0.782671*** (0.027519)		0.666617*** (0.047255)		0.806833*** (0.022622)		0.603913*** (0.055849)	
α^{**}	0.079564 (0.051308)	0.124438* (0.073678)	0.000576 (0.000393)	0.002219 (0.003099)	0.000404* (0.000210)	0.000653 (0.000506)	0.005100 (0.004754)	0.056019 (0.138341)	9.40E-05*** (1.84E-05)	0.000144 (0.000122)
d**	0.167719 (0.115294)	-0.127120 (0.289965)	0.002408 (0.001437)	0.000486 (0.007156)	0.001731* (0.000936)	0.002882 (0.002235)	0.054261 (0.052079)	0.338158 (0.765927)	0.000766*** (0.000154)	0.000193 (0.000169)
Φ_1	1.035415*** (0.143864)	0.949694*** (0.156007)	54.14882*** (9.581530)	50.78871*** (16.79275)	71.41614*** (17.52311)	22.65887* (13.58772)	2.141400 (1.612223)	29.23687*** (7.777291)	51.92421*** (18.46752)	82.10561*** (21.70750)
Φ_2	0.636652*** (0.038328)	0.603851*** (0.037142)	0.803457*** (0.016458)	0.822202*** (0.032570)	0.807321*** (0.030383)	0.844498*** (0.025715)	0.757401*** (0.023233)	0.211766** (0.097430)	0.936222*** (0.008179)	0.908020*** (0.009570)
Φ_3	0.290045*** (0.029430)	0.389600*** (0.038307)	0.236563*** (0.022294)	0.201519*** (0.051491)	0.151719*** (0.025819)	0.185117*** (0.031138)	0.368111*** (0.043852)	0.380434*** (0.087234)	0.064318*** (0.008999)	0.094176*** (0.011088)
Logl	-4724.968	-4657.604	-6271.508	-6255.845	-7025.523	-7129.173	-9145.245	-9159.776	-5757.041	-5750.609
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR						207.299***		29.061***		

Notes: The estimation of the full model containing fundamentalist (α), chartist (d and ω) and noise traders (φ) (A) in comparison with the full model with the restriction of ω to 0 (C). The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients and is left if the restricted model outperforms the unrestricted model. The *, ** and *** are significance at a 10%, 5% and 1% level.

Table 5:3 Estimation of long run versus short run chartists in model with noise trader restrictions

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)
c	0.141610*** (0.054799)	1.059323*** (0.044249)	5.360704*** (0.505998)	2.957803*** (0.649443)	-1.495443 (1.132733)	8.357158*** (1.561057)	2.500267*** (0.284371)	3.352250*** (0.493326)	-16.43525*** (2.511932)	-24.81487*** (2.440849)
α^*	0.034818*** (0.000567)	0.035114*** (0.001219)	0.037738*** (0.001801)	0.042440*** (0.002540)	0.051084*** (0.001252)	0.050321*** (0.002346)	0.044402*** (0.001032)	0.064533*** (0.001759)	0.021369*** (0.001362)	0.027826*** (0.001114)
d*	0.026957*** (0.000568)	0.139795*** (0.019072)	0.103850*** (0.004628)	0.243248*** (0.013539)	0.055549*** (0.001310)	0.208253*** (0.024036)	0.076734*** (0.002338)	0.151121*** (0.015157)	0.179553*** (0.013505)	0.147734*** (0.015050)
ω	0.999983*** (1.26E-07)		0.956355*** (0.003218)		0.998428*** (0.000214)		0.977703*** (0.000848)		0.536487*** (0.042104)	
α^{**}	-1.017238*** (0.000115)	0.060293** (0.019943)	8.72E-05*** (2.73E-05)	0.000478*** (0.000128)	1.00E-05 (1.55E-05)	0.000374*** (0.000127)	3.90E-05*** (1.33E-05)	0.000460*** (6.76E-05)	6.75E-05** (3.36E-05)	0.000131* (7.23E-05)
d**	1.018840*** (9.05E-05)	-0.060969 (0.116482)	0.000711*** (0.000116)	0.000746 (0.000525)	8.14E-05*** (1.59E-05)	0.001023** (0.000441)	0.000777*** (4.54E-05)	0.000507* (0.000266)	0.000719** (0.000342)	0.000309 (0.000200)
Φ_2	0.969127*** (0.000431)	0.960466*** (0.001178)	0.899805*** (0.004627)	0.913257*** (0.004303)	0.928034*** (0.003417)	0.921674*** (0.004574)	0.811892*** (0.005010)	0.889006*** (0.004031)	0.952058*** (0.004081)	0.941504*** (0.004187)
Logl	-4508.244	-4723.169	-6230.595	-6256.445	-6900.095	-7063.982	-9132.349	-9203.971	-5781.379	-5764.130
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR		429.850***		51.700***		327.773***		143.245***		

Notes: The estimation of the a restricted form of the model containing fundamentalist (α), chartist (d and ω) and noise traders (φ) (A*) in comparison with the model with an additional restriction of ω to 0 (C*). The shared restrictions lie in the noise traders constant ($\Phi_1=0$) and restricting the remaining noise trader coefficients to 1 ($\Phi_2=1-\Phi_3$). The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients and is left if the restricted model outperforms the unrestricted model. The *, ** and *** are significance at a 10%, 5% and 1% level.

Table 5:4 Results concerning significance of chartist regime in a model with switch and noise trader restrictions

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(B*)	(D*)	(B*)	(D*)	(B*)	(D*)	(B*)	(D*)	(B*)	(D*)
c	0.340039*** (0.057812)	0.339231*** (0.056449)	-0.613031 (0.745694)	-0.671606 (0.738570)	0.226768 (1.522477)	0.267933 (1.520286)	0.901105 (0.566854)	0.883432 (0.555699)	-4.235157 (3.103813)	-4.223395 (3.104573)
α^*	0.005546*** (0.001248)	0.005265*** (0.001242)	0.011345*** (0.002293)	0.011525*** (0.002286)	0.012423*** (0.002592)	0.012710*** (0.002532)	0.006430** (0.002068)	0.006913*** (0.002069)	0.002507 (0.002188)	0.002403 (0.002118)
d*	0.216720*** (0.020984)	0.223438*** (0.020616)	0.321526*** (0.023026)	0.304696*** (0.022098)	0.305062*** (0.024614)	0.299660*** (0.023783)	0.284221*** (0.015618)	0.277347*** (0.014615)	0.219884*** (0.028047)	0.222489*** (0.026687)
ω	0.147700 (0.093568)		-0.194248** (0.084840)		-0.068681 (0.091240)		-0.123702 (0.076652)		0.056647 (0.143442)	
Φ_2	0.943794*** (0.002116)	0.943569*** (0.002103)	0.953476*** (0.001802)	0.953104*** (0.001850)	0.928035*** (0.004637)	0.928189*** (0.004550)	0.936998*** (0.001729)	0.936515*** (0.001753)	0.952397*** (0.004372)	0.952449*** (0.004291)
Logl	-4890.568	-4891.259	-6326.482	-6328.119	-7191.980	-7192.120	-9343.342	-9343.797	-5885.330	-5885.412
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR		1.383		3.273*		0.281		0.909		0.164

Notes: The estimation of the a restricted form of the model containing fundamentalist (α), chartist (d and ω) and noise traders (φ) (A^*) in comparison with the model with an additional restriction of ω to 0 (C^*). The shared restrictions lie in the noise traders constant ($\Phi_1=0$), restricting the remaining noise trader coefficients to 1 ($\Phi_2=1-\Phi_3$), the switching parameter to 0 ($\beta=0$) and market maker parameter at the value 1 ($\mu=1$). The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients. The *, ** and *** are significance at a 10%, 5% and 1% level.

Table 5:5 Estimation of the significance of chartist traders in model with noise trader restrictions

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(A*)	(D*)	(A*)	(D*)	(A*)	(D*)	(A*)	(D*)	(A*)	(D*)
c	0.141610*** (0.054799)	0.326556*** (0.055762)	5.360704*** (0.505998)	-0.548376*** (0.760087)	-1.495443 (1.132733)	-0.094198 (1.537283)	2.500267*** (0.284371)	-0.255696 (0.312617)	-16.43525*** (2.511932)	-3.971632 (3.071607)
α^*	0.034818*** (0.000567)	0.002950** (0.001325)	0.037738*** (0.001801)	0.009679*** (0.002237)	0.051084*** (0.001252)	0.009635*** (0.002538)	0.044402*** (0.001032)	-0.002698** (0.001274)	0.021369*** (0.001362)	0.000572 (0.002114)
d*	0.026957*** (0.000568)		0.103850*** (0.004628)		0.055549*** (0.001310)		0.076734*** (0.002338)		0.179553*** (0.013505)	
ω	0.999983*** (1.26E-07)		0.956355*** (0.003218)		0.998428*** (0.000214)		0.977703*** (0.000848)		0.536487*** (0.042104)	
α^{**}	-1.017238*** (0.000115)		8.72E-05** (2.73E-05)		1.00E-05 (1.55E-05)		3.90E-05*** (1.33E-05)		6.75E-05** (3.36E-05)	
d**	1.018840*** (9.05E-05)		0.000711*** (0.000116)		8.14E-05*** (1.59E-05)		0.000777*** (4.54E-05)		0.000719** (0.000342)	
Φ_2	0.969127*** (0.000431)	0.941828*** (0.002177)	0.899805*** (0.004627)	0.940791*** (0.002278)	0.928034*** (0.003417)	0.926223*** (0.004733)	0.811892*** (0.005010)	0.876707*** (0.003247)	0.952058*** (0.004081)	0.953349*** (0.004543)
Logl	-4508.244	-4921.326	-6230.595	-6370.380	-6900.095	-7240.607	-9132.349	-9389.637	-5781.379	-5905.358
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR		826.163***		279.569***		681.023***		514.576***		247.957***

Notes: The estimation of the restricted form of the model containing fundamentalist (α), chartist (d and ω) and a restricted form of noise traders (φ) (A^*) in comparison with the model with exception of chartist traders (d and ω are restricted to 0) (D^*). In the more restricted form there is no possibility to switch (β is restricted to 0). The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients. The *, ** and *** are significance at a 10%, 5% and 1% level.

Table 5:6 Estimation of significance of the switching agents

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(E*)	(F*)	(E*)	(F*)	(E*)	(F*)	(E*)	(F*)	(E*)	(F*)
c	0.174573*** (0.059407)	0.237819*** (0.055561)	-1.206686 (0.754275)	-0.760572 (0.784664)	-1.943926 (1.219421)	-1.491877 (1.280343)	0.351967 (0.496760)	-0.030724 (0.273758)	-2.355705 (2.588197)	-3.378843 (2.497119)
d*	0.216344*** (0.019904)		0.300900*** (0.022099)		0.290112*** (0.023398)		0.269227*** (0.014772)		0.219141*** (0.026640)	
Φ_2	0.944035*** (0.001972)	0.941837*** (0.002128)	0.951193*** (0.001793)	0.939930*** (0.002168)	0.913609*** (0.004798)	0.927267*** (0.004644)	0.933067*** (0.001949)	0.879733*** (0.003084)	0.940726*** (0.004415)	0.941028*** (0.004853)
Logl	-4893.537	-4921.999	-6332.636	-6373.375	-7214.177	-7243.867	-9345.714	-9389.989	-5900.250	-5919.098
Obs	1493	1493	1128	1128	1233	1233	1650	1650	948	948
LLR	340.735***	397.660***	152.382***	233.859***	300.389***	359.771***	283.486***	372.035***	272.239***	309.935***

Notes: The estimation of a form of the model with additional restrictions concerning fundamentalist (α) (E*) and chartist (d) (F*) benchmarked against the model with short run chartists ($\omega = 0$) and restricted noise traders ($\phi_1=0$ and $\Phi_2=1-\Phi_3$) (C*). In the more restricted forms there is no possibility to switch (β is restricted to 0). The values between parenthesis are the standard errors of the estimated parameters and the Log Likelihood Ratio (LLR) is the ratio between the unrestricted and restricted model. The LLR shows the significance of the restrained coefficients. The *, ** and *** are significance at a 10%, 5% and 1% level.

Secondly the possible existence of a chartist regime is investigated as a whole. By putting the results of the model with previously described restrictions concerning noise traders against a model with additional restrictions concerning the chartist regime (d and ω are restricted to 0)²¹. The results of this test can be found in Table 5:5. As can be seen in the table the difference between the restricted and unrestricted model is highly significant for all indices. This is an indication that there is or there are chartist(s) regime(s) operational within these markets and this/these regime(s) switch(es) with the fundamentalist regime. Boswijk et al. (2007), and De Jong et al. (2009)

As a final test in this paragraph restrictions concerning fundamentalist and chartist are benchmarked against the model with short run noise traders ($\omega=0$) and restricted noise traders. The results of this last comparison can be found in Table 5:6. It shows the significance of both fundamentalists and short run chartists when restricted. This means there is a significant indication that both these regimes are operational in the chosen European indices and the traders switch between the regimes. The noise traders are also suggested to be operational within the markets as their coefficient is highly significant even when all other traders are restricted.

5.3 The market maker and intensity of choice

After the estimation and valuation of the different regimes the parameters of the market maker and the intensity of the choice to switch are retrieved by minimizing the loss function described in methodology (chapter 3). The results of this mineralisation have to be viewed in the light of the possible bias speculated on by this thesis. Because of the possible impact of the change in ω when restricting the model the estimates are made with both the estimates of the model with a long run chartist and a short run chartist regime. The results of the optimizations can be found in

Table 5:7. With exception of the estimations of the less restricted estimation on the AEX index the parameters have similar values as in the results of Chiarella, et al. (2010). The values of the fundamentalist and chartist coefficients are positive and of small magnitude. This reinforces the idea of fundamentalists who believe prices will return to their fundamental value. These results are also in line with previously found estimates concerning the chartists.

The values of the price adjustment speed parameter of the market maker is also positive and has values surrounding 1. This is line with findings of this parameter in the sub period between 1995 and 2009 researched in Chiarella, et al. (2010). This time period is a big part of the time period researched on the European indices. The value of 1 indicates the market maker instantly adjusts prices to adjust for excess demand or supply. These are not surprising values given the sample frequency. A market maker may not instantly react in day to day excesses. However this sample consists of weekly data.

²¹ Because there is only one regime left which possibly switches the β is also restricted to 0.

The intensity of choice estimation is small and positive which is normal in empirical studies using forms of the ABS model. It implies traders adjust towards trading rules with higher profits. However not instantly. The found values for the parameter are once again highly comparable with the latter subsample test of Chiarella, et al. (2010).

The optimized coefficients in the case of the less restricted model on the AEX index are exceptional. Long run chartists are suggested to have extremely explosive expectations and all switching traders act positive and almost instantly on less profitable trading rules. These results are very unlikely and are possibly caused by suggested bias.

Table 5:7 Implied Structural Coefficients

	AEX		BEL20		CAC40		DAX30		FTSE100	
	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)	(A*)	(C*)
α	0.03482	0.05298	0.03849	0.06693	0.00989	0.06304	0.00483	0.03202	0.01901	0.03356
d	252.751	0.21185	0.31164	0.11373	0.30407	0.17593	0.08484	0.09536	0.15993	0.17768
μ	1.00001	0.65990	0.98007	0.95869	1.00003	1.15968	0.90448	1.5848	1.12433	0.82918
β	-2.9E+07	1.70632	0.00227	0.00656	0.00101	0.00593	0.00809	0.00332	0.00434	0.00174

Notes: The implied values of the impact of the fundamentalist (α) and chartist regime (d), the market maker speed of price adjustment (μ) and the intensity of choice (β). These values are calculated by minimizing the loss function (32).

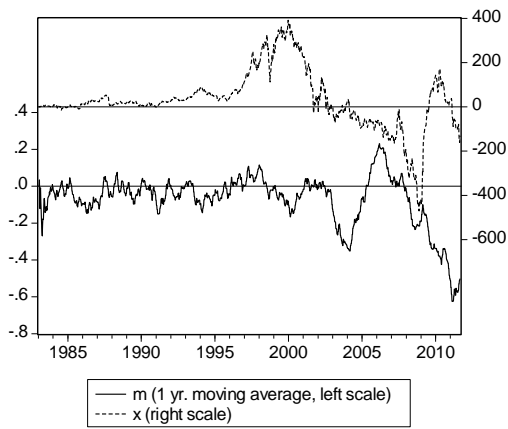
5.4 Switching between trading rules

The estimated weights of the trading regimes show similar patterns. Within the boundaries they seem of extreme chartist and fundamental believes the weight seem somewhat evenly spread with in some cases a small peak at an even spread of the regimes. The extreme cases show relative major peaks (see Figure 8:2). These results are similar for the model with inclusion of a long run orientated and one with a short run orientated chartist. The studies of Chiarella et al. (2010), Boswijk et al. (2007), and De Jong et al. (2009) also find extreme occupations of their regimes. Although the chartist regime has one major peak in the distribution, the fundamentalist are not always fully occupying the market. There are two peaks in which one is extreme and the other almost extreme. Even when fundamental trading rules are the norm within the market there is still influence of the chartist regime. The results concerning the movements of regimes in the study De Jong et al. (2009) also show peaks which are not brought to the extremes.

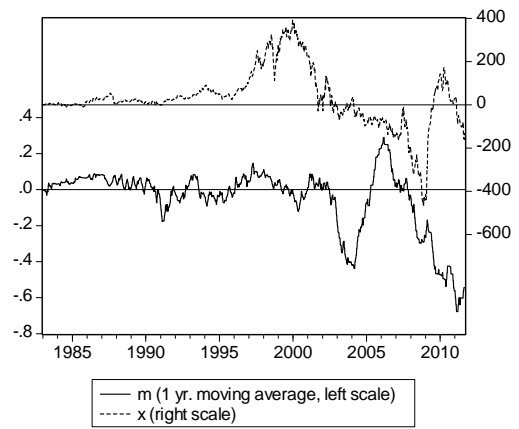
Figure 5:1 Graphs of the difference between price and its fundamentals and trading regime weights

AEX

Long run Chartist

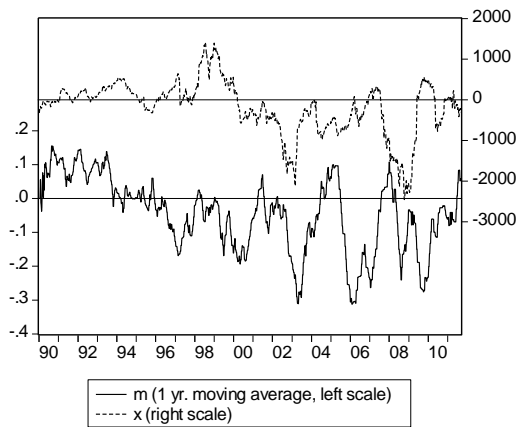


Short run Chartist

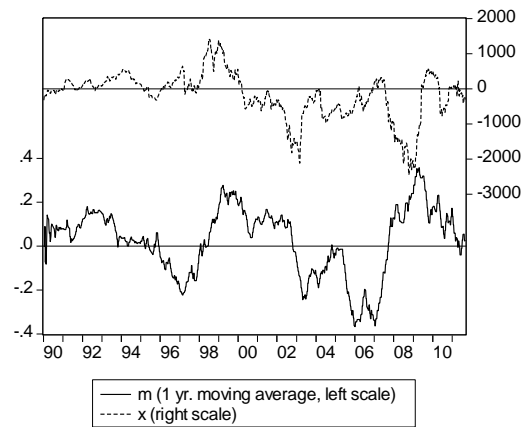


BEL20

Long run Chartist

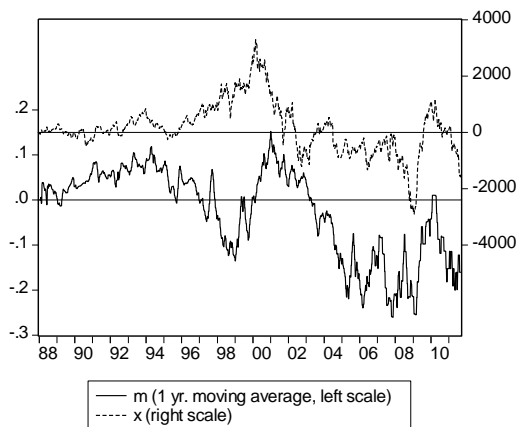


Short run Chartist

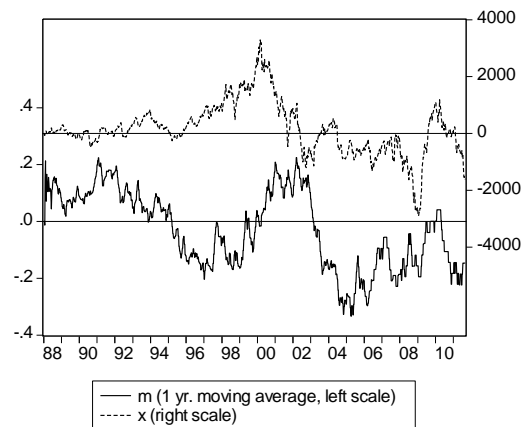


CAC40

Long run Chartist

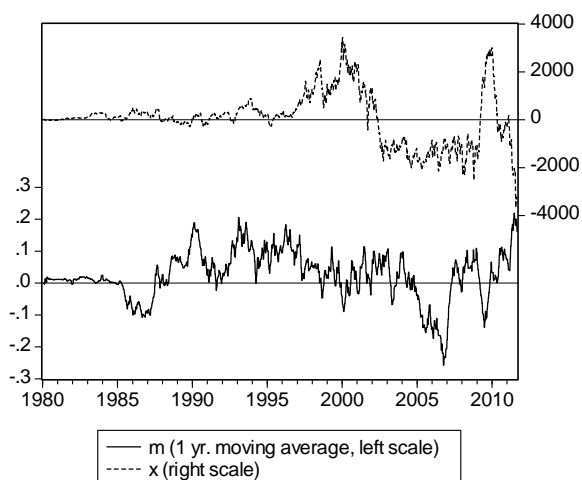


Short run Chartist

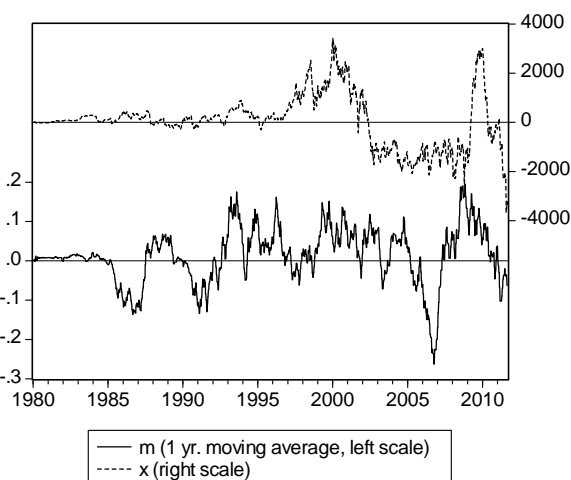


DAX30

Long run Chartist

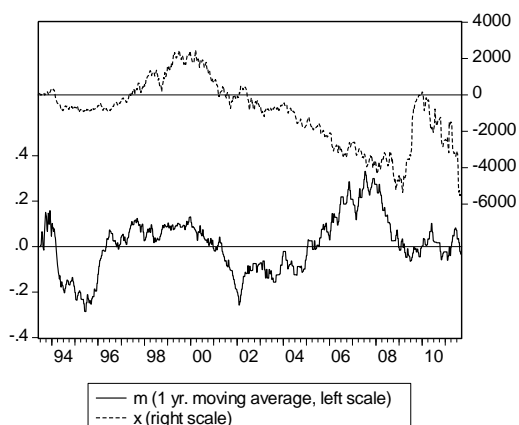


Short run Chartist

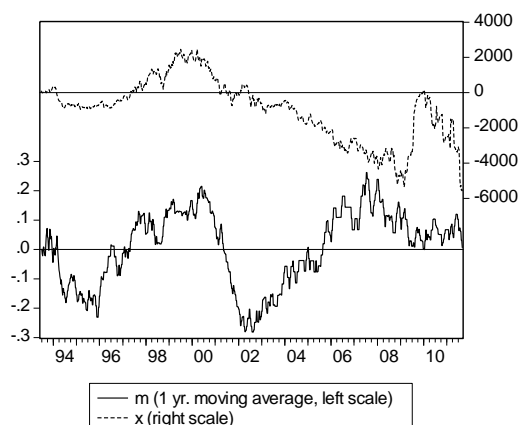


FTSE100

Long run Chartist



Short run Chartist



Notes: The difference between the prices of the indices and their fundamental values (x) against the one year moving averages of the weights of the fundamental and chartist regimes per stock index. The difference x is plotted on the right axis and the weight on the left. The left graphs contain the weights of the fundamental and the long run orientated chartist regime. The right graphs contain the weights of the fundamental and short run orientated regimes.

To investigate the impact of the weight the depended difference between the price of the index and its fundamentals is plotted against the one year average of the weights²². The resulting graphs can be found in

²² As the weights take on extreme values their one period value plots have low explanatory properties.

Figure 5:1. The graphs show similar patterns for the weight of the model with short and long run chartists with exception of the BEL20 index. Overall the patterns can be seen of stabilisation with average weights towards the fundamentalist regime ($m > 0$) and trend following patterns with an average weight towards the chartist regime ($m < 0$). The movements in the difference between price and fundamental indicate the dot com bubble to be an overvaluation and the period before the credit crisis to be a period of no overvaluation or even undervaluation. The reason for this probably through the difference in characteristics as discussed in chapter 4. The fundamentalist regime seems to have less impact on prices. The regimes has to grow and occupy the market for a relatively long time before a trend back to the fundamentals starts. After initiation of the reversions the chartist regimes grow and cause the price changes. The possible reason a big fundamentalist regime does not directly initiate a run back to fundamentals is through their mild expectations²³ and there not fully occupation of the market. They are the biggest group in some periods, but are not alone. Through their mild expectations the fundamentalist regime is able to make profits even when the price is far from its fundamentals.

²³ Expectations of 20-45 weeks before prices return to their fundamentals.

6 Conclusion

This thesis has tried to answer the question if movements in European stock market indices can be explained by heterogeneity of the agents that operate within these markets. It investigates if movements in differences between European stock market prices and their fundamental values can be explained by a market occupation of a fundamentalist, chartist and noise trading regime. It also investigates the impact of the market makers operating in the LSE. This by testing the model of Chiarella et al. (2010) on a sample consisting of AEX, BEL20, CAC40, DAX30 and FTSE100. The sample period varies per index from their various time of foundation until the first week of September 2011.

The results of the test indicate problems concerning the theoretical significance of the noise trading regime. The noise trader results give an indication that noise traders do not create a long run average variance. This violates an assumption underlying the function describing this regime. These results are in contrast to the results of the research of Chiarella et al. (2010).

The results concerning the chartist regime are mixed. When left the possibility to switch between trading rules the coefficients show similar results with the origin research of Chiarella et al. (2010). And results in line with the studies of Boswijk et al. (2007) and De Jong et al. (2009). The chartist seem to use a large portion of past deviations between price and its fundamental price in their estimation of future changes. The positive coefficient in the use of this information is positive and of about the same magnitude suggesting the chartist to expect a long run trend in the deviations. When however left restricted to their trading rule their use of past information seems less pronounced in contrast to the previous study. There is reason to believe the model of Chiarella et al. (2010) does not fully grasp the heterogeneity of the strategies used in markets of the researched sample. The restriction in the model towards a simple AR(1) expectations forming process for chartist has been found insignificant. Based on the contradicting results in comparison with past studies this author speculates a coexistence of two different trading types of chartist. Chartists forming their expectations on long run and short run deviations between the price of the index and its value according to its fundamentals. As the model of Chiarella et al. (2010) is build to switch between two regimes and expansion of the model concerning the possible omitted variable is out of the scope of this thesis.

There is however reason to believe there is heterogeneity in the trading rules used to buy and sell the samples European stock indices. By researching the data significant results concerning a fundamentalist regime, but also a chartist and noise trading regime where found. The estimations of the fundamentalist regime are highly comparable in their value and significance with the studies of Chiarella et al. (2010), Boswijk et al. (2007) and De Jong et al. (2009). Although the form of the

chartist regime is discussable the results concerning the regime are significant and in line qua size and significance with Chiarella et al. (2010). Indicating influence of a form of chartist regime. The noise trading regime is theoretically insignificant. However the coefficients approximating the regime are highly significant. When restricted to not converge towards a long run variance their values are theoretically and statistically significant. There is a significant indication the noise trader regime influences risk in the form of variance by amplifying and smoothing past variance within the researched sample.

The speed of adjustment has been found insignificant, but its importance on the models explanatory power has been found highly significant. This result is line with previous empirical studies on an ABS form HAM, like Boswijk et al. (2007), Chiarella et al. (2010) and De Jong et al. (2006, 2009, 2010). There is reason to believe in an influence of the market makers in the London Stock Exchange. There values indicate a close to but not immediate reaction of the market maker. But through the possibility of an omitted variable bias caution has to be taken in interpreting the results.

For future research an extension of the model used by Chiarella et al. (2010) on stock indices is suggested. For example with addition of second group of chartists. Also an extension of the noise trader regime is suggested, like the use of a different kind of GARCH setup. In the line of assumption concerning the switching of this regime. It is relatively more focused on feeling and market sentiment. Prospect theory, a popular theory in behavioural finance concerning trade sentiment, could explain noise regime to a greater extend. This would lead to the use of QGARCH, GJR-GARCH, or T-GARCH setup. Keep in mind the complexity as the test will mainly require a maximum likelihood estimation which is very sensitive concerning its starting values and especially when models become more complex. A research of the model of Chiarella et al. (2010) on higher frequency data is also interesting. Most prominently for the possible impact of the market maker.

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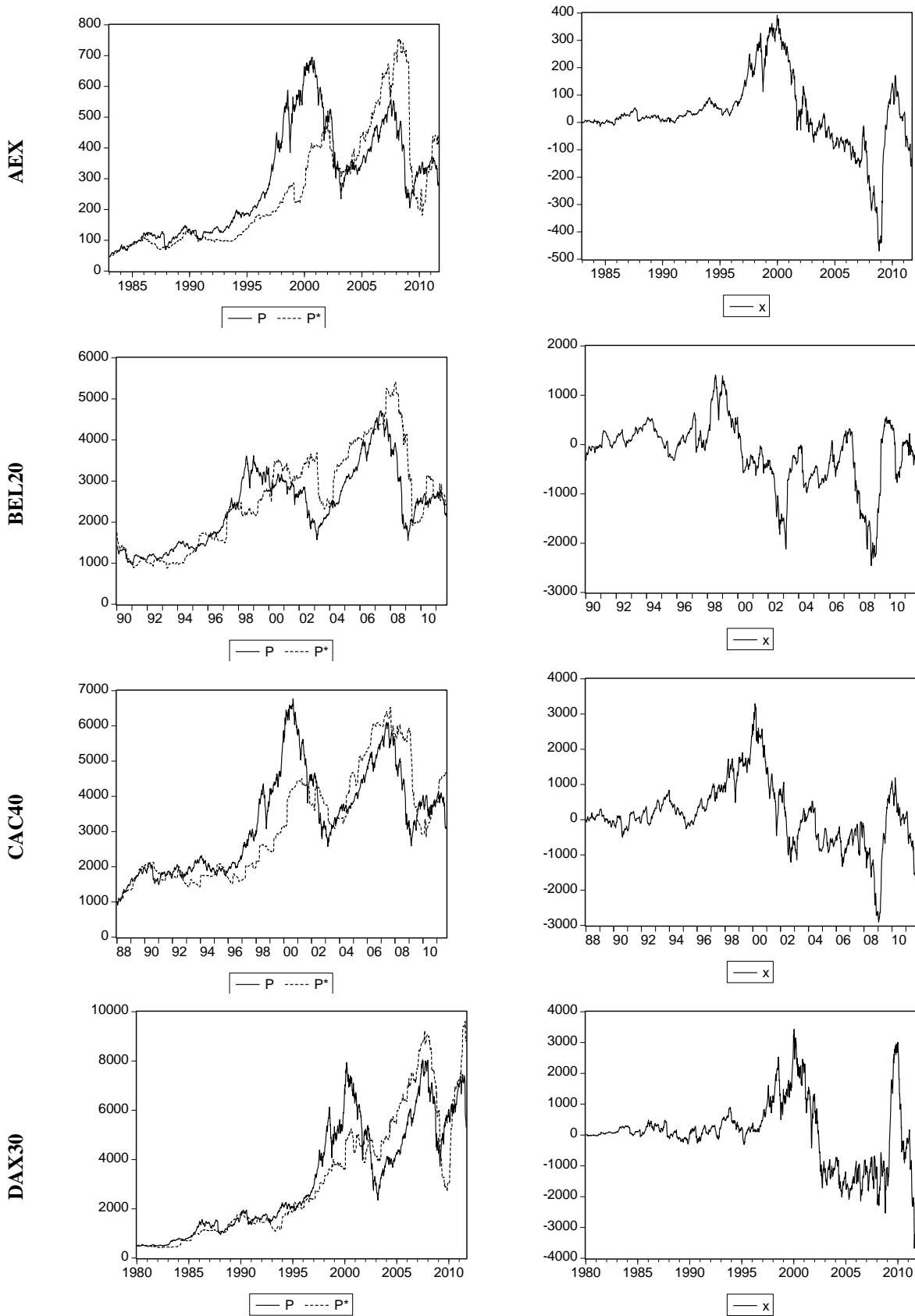
8 Appendix

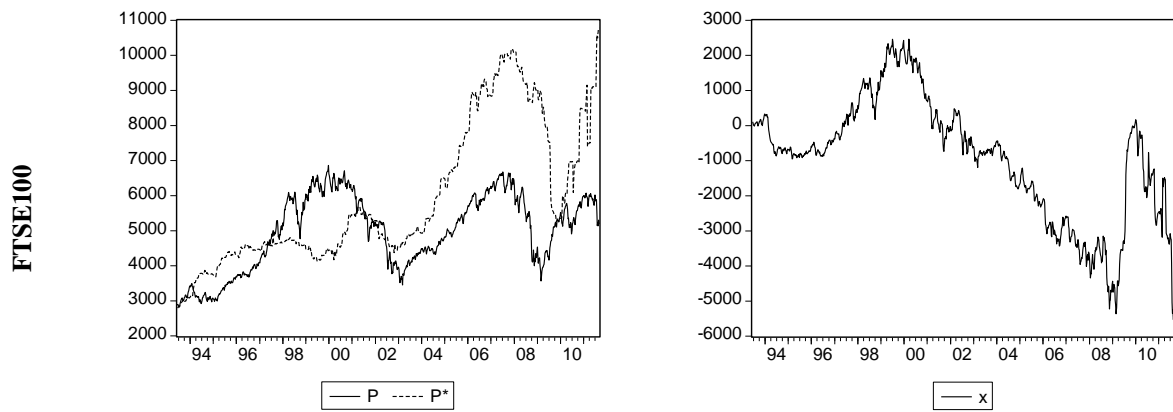
Table 8:1 Indices listed on the London Stock Exchange

Indices	Market	Foundation	DataStream
FTSE 100	United Kingdom	1984	Yes
NASDAQ 100	Global	1985	n/a
S&P 500	United States	1957	n/a
FTSE MIB	Italy	1808	No
DAX 30	Germany	1988	Yes
Eurostoxx 50	Europe	1998	No
CAC 40	France	1987	Yes
AEX	Netherlands	1983	Yes
BEL20	Belgium	1990	Yes
PSI 20	Portugal	1995	No
Nikkei 225	Japan	1950	n/a
Hang Seng Index	Hong Kong	1969	n/a
ASX All Ords	Australia	1987	n/a

Notes: These are the Stock Indices listed on the LSE with exception of few indices consisting of UK companies. Because the LSE is based in London it has many indices listed which consist of these countries. An over representation of these indices is not wanted in this study. The only index of this type which has been put into consideration is the FTSE 100, because of its relative importance and popularity. The market gives information on the considered nationality of the companies of which the index consists. DataStream gives information on the availability of the price and earnings information in DataStream.

Figure 8:1 Real and fundamental price and their differences





Notes: A graph of the price P and fundamental price P^* per stock index within the sample, namely the AEX, BEL20, CAC40, DAX30 and FTSE100 index (left graphs). And graphs of the difference between the price and fundamental price X per stock index (right graphs). The values of the indices vary to a great extent, but the graphs can reveal similar patterns in movements between the indices.

Table 8:2 Augmented Dickey-Fuller test

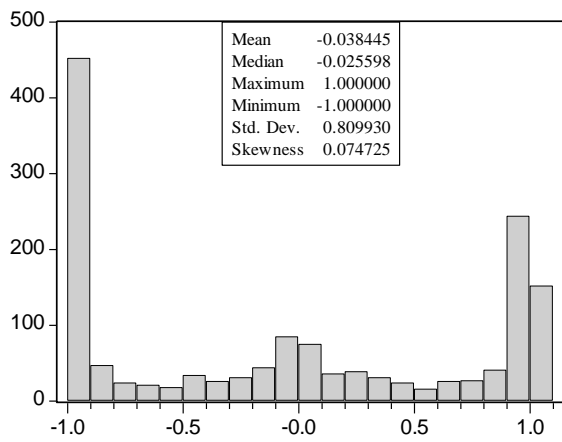
AEX			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-22.62400	0.0000
Test critical values:	1% level	-3.964412	
	5% level	-3.412925	
	10% level	-3.128455	
BEL20			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-25.30564	0.0000
Test critical values:	1% level	-3.966473	
	5% level	-3.413933	
	10% level	-3.129052	
CAC40			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-27.64653	0.0000
Test critical values:	1% level	-3.965731	
	5% level	-3.413570	
	10% level	-3.128837	
DAX30			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-33.47898	0.0000
Test critical values:	1% level	-3.963615	
	5% level	-3.412535	
	10% level	-3.128224	
FTSE100			
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-23.01407	0.0000
Test critical values:	1% level	-3.968144	
	5% level	-3.414749	
	10% level	-3.129536	

Notes: Results of an Augmented Dickey-Fuller test on the differences in variable x. The null hypothesis of the test is a unit root in the variable. Rejection of the null hypothesis is in favour of a possible stationary distribution. All the indices within the sample reject the null hypothesis.

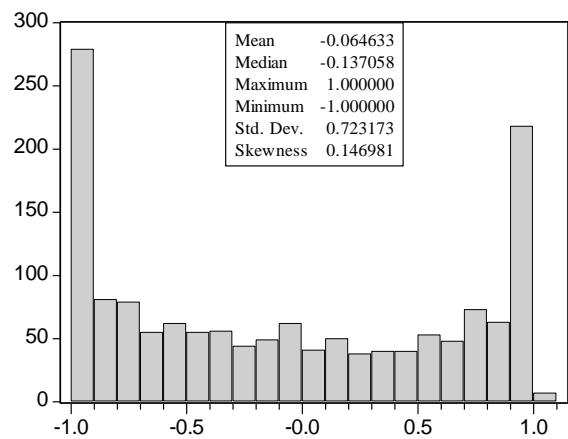
Figure 8:2 Histograms of the weights assigned to trading regimes

AEX

Long run Chartist

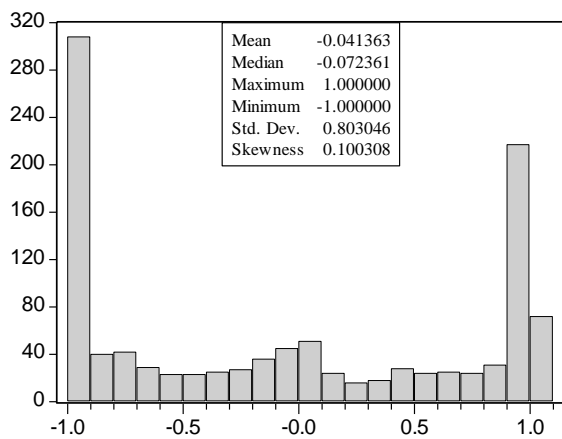


Short run Chartist

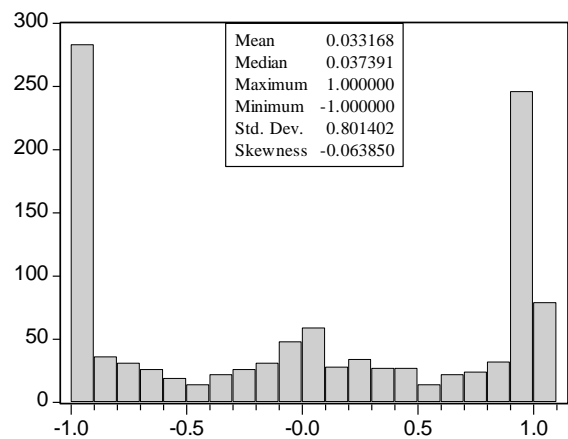


BEL20

Long run Chartist

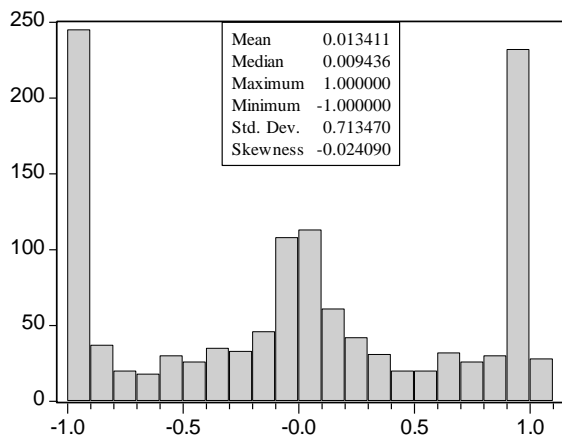


Short run Chartist

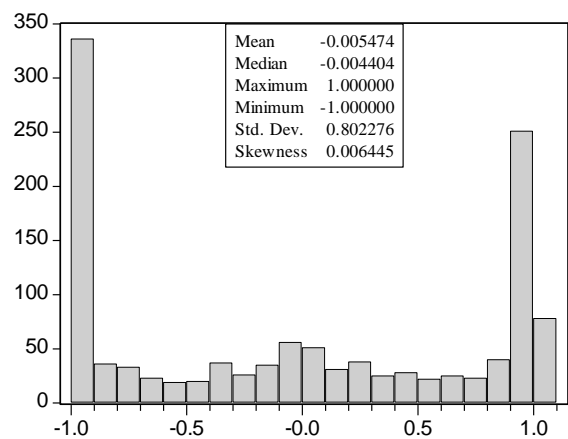


CAC40

Long run Chartist

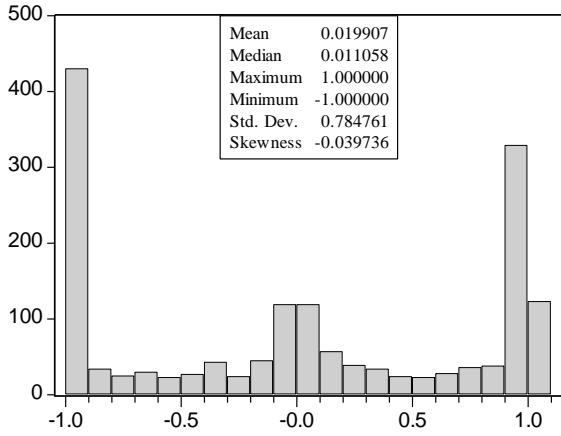


Short run Chartist

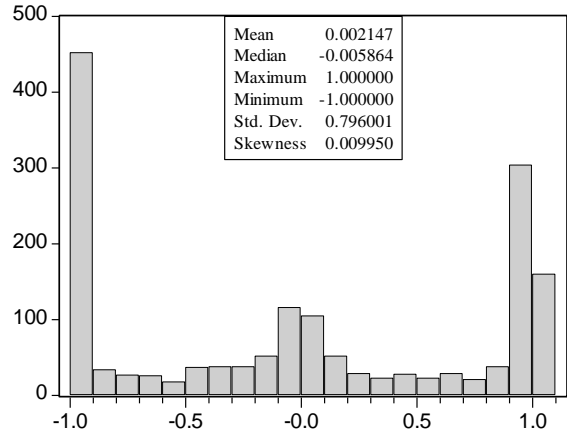


DAX30

Long run Chartist

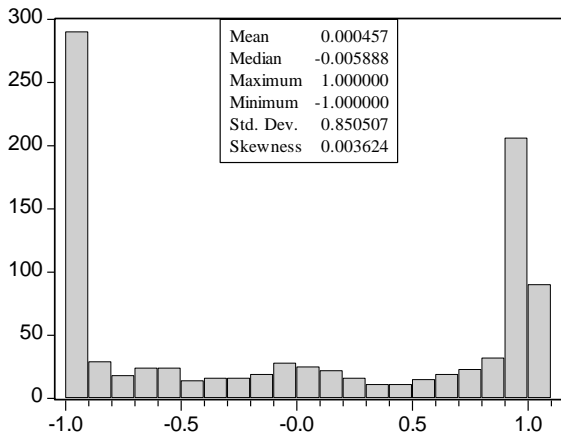


Short run Chartist

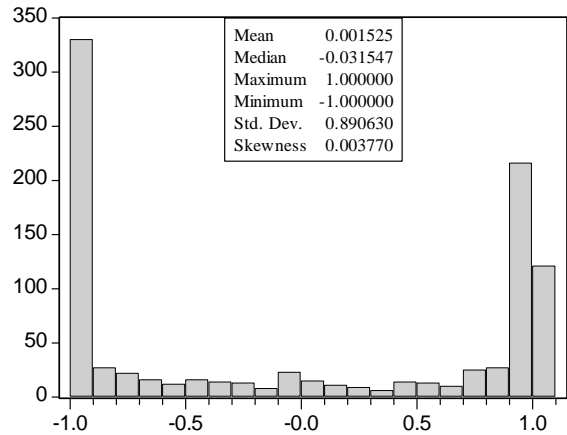


FTSE100

Long run Chartist



Short run Chartist



Notes: Histograms and descriptive statistics of the estimated weights assigned to the fundamentalist and chartist trading regime per stock index. These are estimated in a model with a long run (Left) and short run chartist regime. The weights have values between the boundaries $[-1, 1]$. The extreme value of -1 indicates a domination of the chartist regime and $+1$ a domination of the fundamentalist regime.