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Electrifying Heterogeneous Agents Switching on the European market

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PREFACE AND ACKNOWLEDGEMENTS

In front of you lies my master thesis. A piece of writing which I perceived as the biggest hindrance in my study career. However, during the process I found out that writing a thesis is not so bad at all.

During the months writing this piece I spend most of my days in the university library. Fortunately, friends of mine were writing their thesis as well there and I enjoyed the coffee breaks I had with them. More importantly, this thesis' subject is a combination of two topics which I find to be both very interesting. The electricity market is in my opinion a fascinating field of research and I would not preclude pursuing a professional career in this market segment.
During my study, financial economics, I learned more about the traditional financial models which assume rational, homogenous agents. However, behavioural finance caught my attention, because I believe ignoring human biases is rather ignorant, and incorporating this behaviour into economic models greatly enhances the understanding about economics.

But most importantly, writing this master thesis became such a positive experience due to the great guidance of my supervisor Remco Zwinkels. I would like to thank him for his comments, his suggestions and his patience. I have enjoyed the conversations I had with him about the Box-Jenkins method and my love-hate affair with Eviews. I would also like to thank Ronald Huisman for his elucidation about the electricity market and his guidance. I would like to thank Mehtap Kilic for the data.

Finally, I would like to thank my family. Thanks, mom and dad for your everlasting support and faith in me. Fieke and Amber, my two sisters, thank you for your uplifting words and gestures.

Raquelle Maliepaard,
Rotterdam, April 2010.

ABSTRACT

In this HAM, which is based on the model of Ter Ellen and Zwinkels (2010), we test the presence of heterogeneous agents in three European electricity markets: the APX, the EEX and Nordpool. We make a distinction between fundamentalist and chartists. The former mentioned group of speculators forms expectations about electricity returns based on the fundamental value of electricity. Misalignments between the electricity price and its fundamental value induces traders to buy when it is underpriced and sell when it is overpriced. Therefore fundamentalists have stabilizing effect on the price of electricity. On the other hand, chartists have a destabilizing effect on electricity prices because they trade on price trends. Speculators base their decision which rule to apply on the past profitability of these strategies. The estimation results reveal that both fundamentalists and chartists are present in the electricity market. Especially the presence of heterogeneous agents in the spot markets is remarkable and one might presume that these different agents at least partially determine the spot price of electricity. Speculator in the APX and EEX exchange display rather similar behaviour.

Keywords:
Heterogeneous Agent Models, electricity prices, expectations, behaviour.

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1 - Introduction

The electricity market has only been liberalised since 1990. Before that, the market was regulated by the government and therefore prices could not freely float but were set by the government. During the nineties more and more countries deregulated their electricity market due to, amongst others, the prospect of lower prices.

Electricity prices tend to be very volatile. The main cause of these unpredictable fluctuations in prices is the fact that it is either impossible or economically inefficient to store electricity. Moreover, electricity is a necessary good and due to the non-storability character there are no inventories which can neutralize any discrepancies between supply and demand. Therefore, mismatches between the supply and demand of electricity might result in large temporary price deviations.
However, electricity is not solely a traded commodity any more. It has become a widely traded financial good as well, traded upon by speculators with exclusively financial motives. Their main goals is to make a profit by buying and selling electricity and electricity derivatives, such as futures.

Therefore to examine what kind of effect these speculators have on the price of electricity a heterogeneous agent model (HAM) will be tested in this thesis. HAMs are used in diverse settings and have proven to be particularly useful in explaining price movements in financial markets wherein boundedly rational agents are actively trading. See for example: Cutler et al. (1991), Hommes (2005), Boswijk et al. (2007) and Manzan and Westerhoff (2007). However, these models are not only capable of explaining fluctuations in stock prices and exchange rates. Westerhoff and Reitz (2005), Reitz and Westerhoff (2007) and Ter Ellen and Zwinkels (2010) demonstrate that HAMs are proficient to explain price fluctuations in commodity markets as well. Because, although in these markets producers and consumers trade upon a good for physical delivery, there are also traders active in these markets with purely financial motives: aiming at making a profit on their investment. There is a wide range of agents with heterogeneous expectations and different investment strategies active in these markets which makes a financial-economic model very useful in explaining these price fluctuations. However, up to now, there has not been estimated a HAM with electricity prices as data, to find out whether there are different agents active in the electricity market and whether the trading of these agents can clarify the characteristics observed in electricity prices.

In this HAM, which is based on the model of Ter Ellen and Zwinkels (2010), there are two types of agents with different expectations about electricity prices and returns and therefore they apply different methods in their decision making process. We make a distinction between fundamentalist and chartists. The former mentioned group of speculators forms expectations about electricity returns based on the fundamental value of electricity. Misalignments between the electricity price and its fundamental value induces traders to buy when it is underpriced and sell when it is overpriced. Therefore fundamentalists have stabilizing effect on the price of electricity. On the other hand, chartists have a destabilizing effect on electricity prices because they trade on price trends. They look at previous electricity returns and expect that these returns will move into the same direction in the future. Therefore they extrapolate historical price patterns to exploit investment decisions.

Using electricity prices from three different European electricity exchanges, namely the APX, EEX and Nordpool, this HAM is estimated not only on spot prices, but on 1-, 2-, and 3-year futures contracts as well. The empirical test is twofold: the model will be tested with constant as well as time-varying weights. Using time-varying weights introduces the possibility for speculators to switch between strategies. Whether one will switch or not is based on the performance of both strategies in previous periods.

The empirical results indicate that both fundamentalists and chartists significantly influence the electricity spot price in all three markets. Furthermore, after introducing the possibility to switch between strategies, in general, the statistic plausibility of the model is increased significantly.
When taking a closer look at the movement of chartists and fundamentalists in the different electricity markets we can conclude that the traders in the APX and EEX market display quite similar behaviour, as opposed to traders active on the Nordpool exchange.

The structure of this thesis is as follows: chapter 2 will discuss the liberalisation process of the electricity market. Then we elaborate on the characteristics of electricity prices and discuss which factors determine the price of electricity. Chapter 4 introduces HAMs and chapter 5 continues by discussing the application of HAMs in electricity markets. Chapter 6 gives a description of the empirical model and then we will give a description about the used data and methodology. Chapter 7 presents the empirical results and we will finalize this thesis with concluding remarks and suggestions for further research.

2 - Liberalisation of the electricity market

Until the 1990s electricity markets were monopolies; mostly state-owned, highly regulated utilities with vertically integrated production processes (Newbery 2002, p. 919). Governmental involvement in the electricity sector can partly be explained by the utilities pursuing economies of scale in supply as well as in demand. This created centralized, capital-intensive projects with long payback periods but with services benefiting the entire society (Trevino 2008, p.2). Moreover, in the European Union competition was not allowed because the electricity industry provided services of national interest (Newbery 2002, p. 919). However, after the cold war there was less political concern about the electricity supply due to less risky gas-imports from Russia and an increase in electricity supply made possible by new built gas-fired plants.

Furthermore, during these years the perception that the vertically-integrated monopolies could provide electricity services to consumers cost-efficiently, changed (Jamasb and Pollitt 2005, p. 6).

In the light of a national process of reformation and liberalisation, Britain started as one of the first OECD countries with liberalising the electricity market by creating wholesale electricity markets in 1990 (Newbery 2005). The United States (US) followed with the introduction of the Energy Policy Act in 1992 and several initiatives taken by individual states which facilitated restructured electricity utilities to take advantage of competitive electricity wholesale markets and enabled consumers to choose their own power supplier (Joskow 2001, p. 33).

The US electricity supply is divided between publicly-owned and investor-owned utilities. However, the investor-owned utilities account for the larger part of the US electricity retail sales and most of these utilities were vertically-integrated. Hence, the generation, transmission and distribution of electricity was done by one utility because of complementary operating and investment opportunities in the supply chain and a better capacity adaptation to changing demand and supply (Joskow 1997, p. 120-121).

The electricity prices that the utilities could charge their retail consumers were regulated by state governments and the height of it was based on the utility's 'cost of service' and a 'fair rate of return' on its investments. In return, utilities were obliged to serve all requesting consumers (Joskow 2001, p. 34). These prices are called 'bundled' prices because they are composed of generation, distribution and transmission costs (Joskow 2005, p. 99).

In 1978 the Public Utility Regulatory Policy Act (PURPA) was introduced which required utilities to buy electricity from so called ´Qualifying Facilities´ (QF); mainly other generators and electricity producers who used renewable energy. This Act led to an increase in the number of long-term contracts between vertically integrated and independent utilities (Joskow 1997, p. 124). Due to the agreed long term purchase power contracts and variation in the costs of generation investments between states, there existed large differences in electricity prices between states.

This gap between bundled electricity prices and unbundled prices, prices that would be available in the wholesale market if consumers could buy electricity directly in the market and paying the state or local government the costs for transmission and distribution, contributed to the liberalisation of the US electricity market (Joskow 1997, p. 125 – 126).

After diverse initiatives taken by the Federal Energy Regulatory Commission (FERC) and the introduction of the PURPA, pressures for better available unbundled transmission services and a more competitive market, led to the Energy Policy Act (EPA) of 1992. Among others, this Act increased the FERC´s authority by enabling it to order utilities to supply wholesale transmission service and it relaxed restrictions on US investments in foreign utilities (Joskow 2005, p. 102).

Unfortunately, the availability of transmission service to support the wholesale market increased only minor after the introduction of the EPA. In 1996, these and other considerations led to the introduction of two new rules, initiated by the FERC: Order 888 and Order. Among others, Order 888 requires the transmission owners to open up their networks to third-parties, specifies the types of services that must be made available and what the maximum charged cost-based prices for these services are allowed to be 889 (Joskow 2005, p. 103).

In addition, Order 889 was introduced to improve transmission service by making information about capacity and prices more available. To establish this, it required all public utilities and agents involved in interstate transmission facility services to participate in or create an Open Access Same-time Information System (OASIS) (Joskow 2001, p. 38 - 39). They hoped that by introducing these two Orders, new entrants would be attracted to the market because it would be easier for them to use the transmission network to reach their potential consumers (Joskow 2005, p. 104).

Little by little the US electricity market became more liberalised. Due to changes in the market between 1999 and the introduction of Orders 888 and 889, in 1996, the FERC decided to introduce another Order. Problems such as transmission congestion, discriminatory practices about availability of transmission service and concerns about network reliability resulted in the publication of Order 2000. To resolve these and other issues Order 2000 introduced the 'voluntary' creation of Regional Transmission Organisations (RTOs), which should serve as independent non-profit system operators. Through this Order the FERC tried to establish a platform to encourage transmission and retail competition because it lacked the legal power to restructure vertical and horizontal ownership (Joskow 2005, p. 105). Most states did not react very enthusiastic upon Order 2000, because it seemed like state's political and regulatory power shifted to the federal level. Moreover, the initiated RTOs were not really voluntary and separated the operation from the ownership of the transmission system, which led to a fragmented structure. This became clear when the FERC only ratified two of the ten electricity

markets in the U.S., the Pennsylvania, New Jersey and Maryland (PJM) and New England market, as RTOs (Joskow 2005, p. 107).
The hostility of the different states against electricity market liberalisation became even more clear after the proposal of the FERC to introduce a Standard Market Design (SMD) in 2002. According to the FERC this proposal was necessary because Order 2000 was implemented only at a very slow pace and there still remained inefficiencies in the wholesale power markets. However, due to the California electricity crisis and the Enron scandal several state regulators and members of the Congress opposed to the SMD initiative and therefore it was not implemented (Joskow 2005, p. 108).

The year 2005 is a turning point for the FERC's level of authority. With the enactment of the Energy Policy Act of 2005 the FERC gained new responsibilities and it regained confidence of the Congress. With this law, competition in wholesale power market became national policy. Furthermore, the FERC's regulatory tools were reinforced and new tools were added. In addition, it provided for an improvement of the energy infrastructure to increase the reliability of the Nation's transmission grid. Finally, in 2007, The FERC adopted a final rule which must assure that transmission service is provided on a non-discriminatory basis and it must contribute to a more transparent and decisive regulation (FERC 2009). For more information, see Joskow and Schmalensee (1983).

Because the liberalized British energy market and most of the liberalized US states demonstrated to have lower electricity prices than non-liberalized markets, the European Union (EU) decided to open up its own electricity market for competition (Joskow 1997, p. 124). Furthermore, EU member states showed large deviations in electricity prices among each other, resulting in unfair competition internally. With the opening of the internal market, the EU wanted to establish a more efficient market, upgrade the services from electricity companies, give consumers the opportunity to choose their own electricity provider, cut down on reserve production capacities and improve its own position in the global economy (EC 1999, p .5).

The need to achieve greater economic efficiency was not the only factor contributing to the EU liberalisation process. Due to technological innovation the generating monopolies, once justified by their economies of scale, became redundant. Natural gas-fired small-scale plants partly replaced the large-scale generators and made competition possible in the generation sector. Moreover, through the electronic revolution, there is more information available about operations, the supply and demand of electricity and electricity prices. This has resulted in a wider choice of products and a better match of demand with supply and therefore efficient market prices (Trevino 2008, p. 3 - 4).

To establish a liberalised, more efficient electricity market, the European Union published two Directives. The 1996 Directive specified the opening of electricity markets on the national level

(Jamasb and Pollitt 2005 p. 6). Its intension was to split the electricity industry into four processes: generation, transmission, distribution and (retail) supply. Because transmission and distribution are natural monopolies, only the sectors generation and supply could be opened up to competition (Trevino 2008, p. 4, and Bunn and Karakatsani 2003, p. 3). See for more information about these fore processes Joskow (1997).

Due to the subsidiary principle, which allows each member state to implement the Directive in its own manner, there existed large differences in the level of liberalisation between member states. For example, while in 2001 Sweden and Germany had entirely liberalised their markets, the French and Greek market share that had opened for competition was rather low (Ringel 2003, p. 486-487). Therefore, in 2003, the EU introduced a second, more rigorous, electricity Directive which stipulated full market opening by separating, legally and managerially, the different sectors in the electricity production process and thereby creating more competition (Jamasb and Pollitt 2005 p. 6, see also Trevino 2008, p. 5).

Liberalisation of the electricity market is still a process in development. To gain more understanding about the electricity market, the next section will discuss some characteristics of this market and will discuss what factors are of influence on the price of electricity.

3 – Electricity prices and characteristics of the electricity market

Electricity prices are characterized by high volatility. There are several factors which explain this observed phenomena. One important characteristic of electricity is that it is either impossible or economically inefficient to store. As a consequence there is no inventory which can function as a buffer to solve mismatches between supply and demand, contrary to storable commodities. Therefore, mismatches between the supply and demand of electricity might result in large temporary price deviations (Cartea and Villaplana 2007, p. 4, and Bunn and Karakatsani 2003, p. 3). Although electricity prices display high levels of volatility in the short run, in the long run prices demonstrate mean-reversion. This means that in the long run prices converge to an overall equilibrium value which is determined by the cost of production (Bessembinder and Lemmon 2002, p. 1347,1348, Cartea and Figueroa, 2005, p. 2, and Huisman and Mahieu 2005, p. 426)

Not only the non-storability nature of electricity adds to the high level of volatility in prices, the characteristics of electricity demand and supply contribute as well. Because electricity is a necessary commodity, aggregate demand is highly inelastic. In the short term weather conditions can cause sudden shocks to demand. Furthermore, in extreme cold or warm months demand for electricity increases due to heating and cooling processes which causes seasonal trends in electricity prices. Economic activity influences electricity demand in the short run as well as in the long run. Demand for electricity is higher on working days and on these days demand is highest during morning and evening hours which causes higher electricity prices than on the remaining hours and days (Cartea and Villaplana 2007, p. 4 and 9). The growth in demand is another factor influencing the price of electricity (Brooks and El-Keib, 1998, 174).

Besides the inelasticity in demand, the characteristics of electricity supply aggravate the adverse effects caused by the non-storability feature of electricity. In the short run technical failures of generation plants or transmission congestion can result in instant decrease of electricity supply. Because electricity demand has to be matched with electricity supply these problems must be resolved by using more expensive stand-by generators to produce, and local distributors to supply the demanded electricity, which results in price spikes of short duration (Bunn and Karakatsani 2003, p. 5).

In the long run the market power of generation companies is of influence on the equilibrium price. Throughout history the electricity market has been characterised by large vertically-integrated firms. Although, the market has been deregulated and competition introduced, in most power markets the majority of electricity generation has been executed by a few firms. Therefore, the actions of one supplier may be of influence on the equilibrium price (Cartea and Villaplana 2007, p. 4). Moreover, Bunn and Karakatsani (2003, p. 6) come to the conclusion that this market power causes electricity prices and their accompanying volatility to be higher than would be suggested by their fundamentals.

Another factor of influence on electricity prices is the investment characteristic of electricity producers. Due to economies of scale, investments in generation plants are not gradually conducted but in large tranches. This results in unstable electricity prices around these investment steps (Cartea and Villaplana 2007, p. 4). Related to this, technological change in the electricity sector, which results in better performing generation units, greatly influences the electricity price (Brooks and El-Keib, 1998, p. 174).

Furthermore, the input factors to generate electricity differ across countries and regions. Power producers might even have a site which uses different input factors in its power generation process (Cartea and Villaplana 2007, p. 4). Because the marginal costs of these input factors differ, electricity prices differ per region and change over time. At hours when demand is very high, all generation plants, even the ones with expensive input factors, must be active to generate the level of demanded energy. Therefore, the marginal plant will determine the electricity price.

Also, prices of input factors change over time and result in electricity price changes. A rise in the oil price leads to a higher price for natural gas and eventually indirectly will result in a higher electricity price. In Europe this dependency of electricity prices on oil prices is evident due to the fall in investments in nuclear energy. Since this lack of investment, gas and coal power stations have become marginal power plants, which determine equilibrium prices, and therefore the European price of electricity is largely dependent on the oil price (Percebois, 2008, p. 4).

Finally, the location of the generation plant can influence the price of electricity. Transmission line constraints, such as voltage constraints, can be referred to a transportation costs which increases the price of electricity (Brooks and El-Keib 1998, p. 175 and Longstaff and Wang 2004, p. 1882).

4 – Heterogeneous Agent Models

Ideas about finance have changed through the years. During the 1960's and 1970's the introduction of the Capital Asset Pricing Model (CAPM), the efficient market theory and the initiation of the option-pricing theory based on arbitrage enriched the neoclassical finance literature (Shiller 2006, p. 2). These theories and models are based on rational behaviour, which concerns two aspects. Firstly, rational agents have rational expectations. This means that when they receive new information they update their beliefs correctly, without forecasting errors, in accordance with Bayes law. Therefore expectations are, on average, in accordance with realizations under rational agent theory. Secondly, given these beliefs agents make choices based on an optimization principle. These decision rules are, for example, based on the maximization of utility or profit (Hommes 2005, p. 2 and Barberis and Thaler 2003, p. 1053).

Thus, under rational expectations theory, agents have access to all sources of information and are able to process it correctly. Therefore they are able to determine the true or fundamental value of assets because they have the capability to determine future cash flows of an asset and can discount its sum with a discount rate that is correctly adjusted to their preferences (Barberis and Thaler, p. 1054). This concept is also known as the Efficient Market Hypothesis (EMH). Because all information is incorporated agents can not predict prices and therefore the best predictor of tomorrow's price is today's price, hence prices follow a random walk. Within this theory all agents are rational and hence, have the same expectations. Due to this homogeneity the rational agent is also named the representative agent (Zwinkels 2009, p. 3).

Because agents can determine an asset's fundamental value, any deviation from this fundamental value will immediately be corrected by rational agents through buying undervalued and selling overvalued securities in the market. For example, when a certain asset is overpriced, a trader can gain by simultaneously selling the overpriced asset and buying a similar asset to hedge the risk. This trading will induce the overvalued asset to return to its fundamental value.

However, in the 1980's, it became clear that there existed several anomalies in the market which could not be explained by EMH. EMH was challenged on theoretical ground as well as on empirical ground. According to EMH all traders are identical, rational agents who know that all other traders are rational traders as well. With one type of agent in the market, there will never arise any form of trade. However, there were large levels of trading volume observed in the market (Hommes 2005, p. 3). Furthermore, stock prices revealed volatility levels that did not correspond to the movement in its fundamental factors (Hommes 2005, p. 3 and Shiller 2003, p. 84).

Therefore it has been suggested that the deviations from fundamental values have been caused by agents who are not fully rational (Barberis and Thaler 2003, p. 1054). Traders who do not make trading decisions based on fundamental information, but base their decisions on the actions of other traders, follow trends and act irrational on noise are named 'noise traders' (De Long et al. 1990, p. 704). This led to the idea there are different traders active in the market, ranging from rational to irrational. Everything in between these two types are called 'boundedly rational agents'. Although they use some kind of maximisation process, boundedly rational agent use erroneous models, base their trading decisions on incomplete information or are unable to process the information correctly to make efficient trading decisions (Zwinkels 2009, p. 6).

In addition, due to developments in psychology and sociology the knowledge about human behaviour has grown since the 1980s. The challenge to incorporate these findings into finance, led to a new school within economics, behavioural finance.

Behavioural finance is based on two pillars: cognitive psychology and limits to arbitrage (Ritter 2003, p. 429). The psychology part encompasses human biases such as overconfidence and anchoring which leads to decisions taken by traders who do not necessarily act as a theoretical rational agent would and therefore the outcomes deviate from the Efficient Market Hypothesis (Barberis and Thaler 2003, p. 1063 - 1067).

A requisite for the EMH is that when prices do deviate from their fundamental value, rational agents will notice and take positions to bring back the price to its fundamental value. In order for rational agents to act upon this mispricing arbitrage has to be risk- and costless. However, implementation costs, fundamental risk and noise trader risk restrain traders from correcting price deviations. This is the second pillar of behavioural finance; limits of arbitrage (Barberis and Thaler 2003, p. 1055 – 1057).

Although there may be traders active in the market who are able to determine the fundamental value of an asset, the presence of noise traders in the market results in noise trader risk.

When noise traders actions cause an asset's price to deviate from its fundamental value and rational arbitrageurs recognize this profit opportunity and will act upon it by selling an overvalued asset and/or buying an undervalued asset, there exists a risk for rational arbitrageurs that the asset's price will not mean revert and might deviate even further from its fundamental value due to noise trader's actions. Hence, even without fundamental risk, the existence of noise traders in the market and their unpredictable expectations and actions may restrain arbitrage and result in significant price deviations from an asset's fundamental value.

By bearing this noise trader risk, noise traders can earn a higher expected return than arbitrageurs acting against this deviation. With this in mind it becomes more attractive for traders to go with the noise trader's flow (De Long et al. 1990, p. 705 - 706).

This trading opportunity has been confirmed by several articles. Cutler et al. (1991) examine a rather diverse dataset, consisting of stocks, bonds, real estate, collectibles, precious metals and foreign exchange. Finding positive autocorrelation of asset returns in the short run, negative autocorrelation of returns in the long run and a reversion toward fundamental value in asset prices, in not just one, but several of these markets, indicate the presence of different types of traders. In another paper, Cutler et al. (1990) have outlined a model which specifies three different types of traders: rational traders, fundamental and feedback traders. These latter traders base their trading decisions upon past returns in stead of future fundamentals. They confirm the results generated by De Long et al. (1990); because stock returns exhibit first-order autocorrelation a feedback trader can make a profit by implementing a positive feedback investment rule in the short run (Cutler et al. 1991, P. 66).

Hence, in contrast to the EMH, behavioural finance argues that although price deviations from the fundamental value create profit opportunities, they will not always be exploited due to the risks and costs. The above describes behavioural finance, that introduced next to the representative rational agent also other types of agents and thus moved from the homogeneous agent to heterogeneous agent theory. Heterogeneous Agent Models (HAMs) depict expectations and behaviour of heterogeneous agents and it models the formation of equilibrium prices through their interaction. Furthermore, after each period agents evaluate their strategy by comparing their expectation with the eventual result. When the realised outcome differs from what the agent expected it to be, he might reconsider its strategy and switch to another strategy. However, due to the status quo bias agents react with a certain delay. Therefore a market in which two types of agents interact and they have the possibility to switch to the other agent's approach, their strategy's performance determines the relative weight of the agents in the market and therefore affects the market conditions (Zwinkels 2009, p. 6).

Most HAMs distinguish, within the pool of traders, two types of agents: fundamentalists and chartists. Fundamentalists are agents who use market fundamentals, such as dividends and earnings, to determine their expectations about future asset prices. An asset traded above its fundamental value will be sold by fundamentalists and an undervalued asset will be bought in order to make a profit. Therefore, fundamentalists have a stabilizing effect on the market because their actions will induce asset prices to return to its fundamental value. In contrast with fundamentalists, chartists, or technical analysts, have a destabilising effect on the market. This is because chartists use historical price changes and trends to form expectations about future prices. Hence, chartists do not use fundamentals to determine prices but extrapolate historical price patterns to exploit investment decisions. Survey data shows that chartist strategies are often used in short term decisions and mean-reverting fundamentalists trading rules in the long run (Hommes 2005, p. 4 - 6).

HAMs are used in diverse settings and have proven to be particularly useful in explaining price movements in financial markets. There are a large number of studies which indicate the existence of fundamentalists and chartists and their impact on assets prices, exchange rates and commodity prices as well.

By examining yearly S&P 500 data, Boswijk et al. (2007, p. 14, 24 - 25) demonstrate the existence of significant heterogeneous behaviour in the U.S. stock market. In their model there are two types of traders active, fundamentalists and chartists, who all know the fundamental value of a stock but differ in their opinion about the persistence of price deviations from this value. Furthermore, the switching mechanism allows traders to move to the strategy which had the highest realized profits in the recent period. Therefore, price fluctuations induce traders to follow the trend and implement the chartist strategy. However, periods with only minor price changes induce agents to believe that this deviation is only transitory and therefore traders will adopt the fundamentalist strategy. The results of this model serve as an explanation for the overvalued stock market occurring during the late nineties.

When looking at studies about fluctuations in exchange rates, several studies have found that in the short term exchange rates are driven by technical analysis and overreaction to news. In the long term fundamental factors influence the expectations of traders about the course of the exchange rate (Manzan and Westerhoff 2007, p. 112). However, Manzan and Westerhoff (2007, p. 126) also find that chartists can have a stabilizing effect on the exchange rate when they detect an absolute change in the exchange rate beyond a certain threshold, chartists expect that the exchange rate will reverse in the next period. When the change in the exchange rate remains below the threshold, chartists believe the trend will persist and therefore they have a destabilizing effect on the exchange rate.

Not only are HAMs applied to explain fluctuations in stock markets and exchange rates, they are proficient to explain price fluctuations in commodity markets as well. Because most commodities are traded on exchanges their prices might be influenced by the activities of speculators (Westerhoff and Reitz 2005, p. 642).

Commodity prices demonstrate a strong cyclical pattern. Furthermore, slumps and booms are characterized by their large amplitude. Different studies have confirmed that these price fluctuations in different commodities are caused by speculative behaviour of fundamentalists as well as chartists (Reitz and Westerhoff 2007, p. 232).

Schwartz and Smith (2000) develop a model in which they are able to describe the stochastic behaviour commodity prices exhibit. Using oil futures and forward contracts their model allows oil prices to mean-revert in the short-run and allows these prices to revert to an uncertain price level.

He and Westerhoff (2005, p. 1581 -1582) develop a HAM to model the volatile price characteristics of commodity prices. The group of market participants which influence the price level consists of producers, consumers and speculators. The latter group is further divided into fundamentalists and chartists. When commodity prices are above the fundamental value, chartists expect it to increase further and therefore they will buy the commodity. Vice versa, when the price is below its fundamental value, chartists expect a further decrease. When the price deviates further form its fundamental value, speculators will switch to the fundamentalist's strategy because the risk that the bull market turns into a bear one, and vice versa, increases and therefore the fundamentalist's strategy becomes more attractive. Their results show that when speculators react only minor to the deviation between the fundamental value and the market price, they can push the market into a bull or bear stadium. When they react very strong and quick upon the deviation they cause market prices to fluctuate erratically between bull and bear markets (He and Westerhoff 2005, p. 1593).

Reitz and Westerhoff (2007, p. 243) find similar results. Their HAM shows that more fundamentalists will become active in the market when a commodity's market price (commodities examined are: cotton, soybeans, lead , sugar, rice and zinc) deviates further from its fundamental value. However, when the market price is near its fundamental value the likelihood of mean-reversion is lower and therefore the impact of fundamentalists is relatively low. This combined with the presence of chartists in these market may explain the large fluctuations in commodity markets.

When looking at the US corn market Westerhoff and Reitz (2005, p. 646) conclude that the entrance of technical traders in the U.S. corn market increases when the prices deviates further from its long-run equilibrium. Their impact results in a emergence of pronounced bull and bear periods in the corn market (Westerhoff and Reitz 2005, p 647).

These contradicting conclusions arise due to the assumptions made in the different models. Where Reitz and Westerhoff (2007, p. 235) assume that at least 50 percent of fundamentalists are active in the market and that their weight can increase up to a 100 percent when the mispricing in the market increases, Westerhoff and Reitz (2005 p. 644) assume that at least 50 percent of chartists are active in the market and their impact can go up to a 100 percent when the market price deviates further from its fundamental value.

Oil is yet another commodity of which its prices display high levels of volatility. Ter Ellen and Zwinkels (2010) examine the expectations of different types of agents on the oil price. By introducing fundamentalists, chartists and real market participants who supply and demand oil, and allowing the speculators to switch between strategies based on its performance in the previous period, they find significant results for the fundamentalist as well as the chartist strategy. Therefore, their HAM is capable of explaining, at least partially, the fluctuations observed in oil prices

5 – HAMs in electricity markets

As explained above, in diverse markets there are different kind of traders active which influence commodity and stock prices as well as exchange rates. The electricity market displays, just as these former mentioned market, large fluctuations in the level of its market prices which might indicate the presence of heterogeneous agents in this market and their influence on the price of electricity.

Furthermore, as mentioned in their study, Longstaff and Wang (2004) recognize that there are a lot of different players active in the electricity market and therefore they divide the PJM electricity market participants into five groups. Firstly there are the generation owners who own the generation plants active within the PJM system and converts an input (fuels or renewable sources of energy) into electricity. The second group consists of transmission-owners who transfer electricity from the power plants to wholesale purchasers or local distribution centres. Then the electric-distribution centres make sure that the electricity is transferred from these distribution centres to homes and businesses. Retail end users are the fourth sector and the final group of market participants consist of participants not already mentioned in one of the other groups, such as trading firms and salesmen. However, it is rather difficult to identify these market participants as pure suppliers or demanders of electricity. For example a generation plant might fail to meet its obligations due to a breakdown in the production process. This will turn the generation firm from a supplier into a buyer of electricity. As a result of these market characteristics there are a lot of different participants active in the electricity market who have diverse trading motives and might change their strategies due to changes in the market (Longstaff and Wang 2004, p. 1880 - 1881, Brooks and El-Keib 1998, p. 171).

The existence of these different players in electricity markets indicate that a HAM could be a realistic model to examine the drift of electricity prices. However, as opposed to this idea Longstaff and Wang (2004) conclude that forward prices in the PJM market are rationally determined by risk-averse agents. They support the results found by Bessembinder and Lemmon (2002) that the electricity spot price variance is negatively related to the forward premium and that the price skewness of the spot price is positively related tot the forward premium (Longstaff and Wang 2004, p. 1878). Furthermore the forward risk premium is positively related to price, quantity and revenue uncertainty. Hence, they conclude that the PJM electricity prices react to fundamental economic risks (Longstaff and Wang 2004, p. 1894). Avsar and Goss (2001) conclude exactly the contrary. Conducting a forecast error approach, which assumes that relevant public information can be indicated by prior forecast errors, with future contracts of the California Oregon Border and Palo Verde, they conclude that the EMH should be rejected.

Other studies have pursued to simulate the electricity market with diverse computer programs. For example Praça et al. (2003) have developed a simulation model which studies electricity market behaviour and its evolution. In this model and in other simulations there are a variety of market participants included into the program. Traders are considered to be one group of these market participants.

Hence, although the electricity market has been deregulated only recently, there exist already a diverse compilation of literature about this subject. Market power, determinants of electricity prices, characteristics of prices are only a few topics which have been discussed in different studies.

However, there has not been, up to now, a model (HAM) which divided the traders, into two different groups, fundamentalists and chartists, to find out whether there are different agents active in the electricity market and whether the trading of these agents can clarify the characteristics observed in electricity prices.

6 - Model

To examine whether there are different types of speculators active in the electricity market a Heterogeneous agent model will be applied to three European energy exchanges. The model used to determine whether a heterogeneous agent model can explain de fluctuations observed in electricity prices is based on the model of Ter Ellen and Zwinkels (2010).

In the HAM examined in this empirical study, there are two types of traders active: fundamentalists and chartists. These agents trade on electricity and the investment decisions they make, whether they will buy or sell electricity, are based on different expectations and accompanying strategies. Although electricity is a commodity and therefore produced by several production facilities and used by lots of consumers, it is also a good traded upon by speculators with solely financial motives. In this empirical model there will be examined what kind of effect the latter group has on electricity prices, how they form expectations, and what strategies they apply to determine whether to buy or sell electricity as a financial product. When we refer to electricity, not electricity as a commodity is meant, but as explained above, we refer to electricity as a financial trading good.

As already earlier fundamentalists calculate the fundamental value of electricity to evaluate the market and to determine, based on this value, whether electricity is over- or undervalued and then decide whether they will buy or sell electricity. When the current market price of electricity is above (below) the calculated fundamental electricity price, the fundamentalist will sell (buy) the electricity in order to make a profit. Therefore, fundamentalists have a stabilizing effect on the market price of electricity. Their demand for electricity is given by the following linear formula.

$$D^f{}_t = \alpha^f [E^f{}_t(P_{t+1}) - P_t]$$

Where

$$E^f{}_t(P_{t+1}) = P_t + b^f(P_t - F_t)$$

And hence,

$$D^f{}_t = \alpha^f \left[b^f \left(P_t - F_t \right) \right] \qquad (1)$$

Where $D^f{}_t$ represents the demand of the fundamentalists for electricity at time t. P_t is the log price of electricity at time t and F_t is the log fundamental value of electricity at time t. Because electricity prices mean-revert, the fundamental value of electricity can be estimated by the mean price. It is expected that the variable α^f will have a negative value, due to the stabilizing nature of the fundamentalist's strategy: when the price of electricity is above (below) its fundamental value fundamentalists will sell (buy) electricity and therefore demand decreases (increases).

The other group of agents, the chartists, base their buying and selling decision on price trends. Their demand functions is given by:

$$D^c{}_t = \beta^c (E^c{}_t (P_{t+1}) - P_t)$$

Where

$$E^c{}_t (P_{t+1}) = P_t + \sum_{i=0}^{I} b_i^c (P_{t-i} - P_{t-1-i})$$

And therefore,

$$D^c{}_t = \beta^c \sum_{i=0}^{I} \left[\left(b_i^c \left(P_{t-i} - P_{t-i-1} \right) \right) \right] \tag{2}$$

Where P_{t-1} is the log price of electricity in the previous period. It is expected that the variable β^c is positive because chartists trade on price trends. Therefore, when the return on electricity in the previous period was positive (negative) then the chartist will expect that the current return on electricity will be positive (negative) as well and therefore its demand for electricity will rise (fall). Because chartists trade on price trends, they will examine the previous returns of electricity, to determine their current demand.

Within this HAM traders have the possibility to switch between the fundamentalists and chartists strategy. The choice which strategy to apply or the decision to switch to the other strategy is based on how these trading strategies performed in the past. When the fundamentalist strategy performed better in the past than the chartist strategy agents will prefer the former strategy. The performance of a strategy is based on the forecasting errors of the specific strategy.

Since fundamentalists estimate the expected price of electricity by determining the fundamental value of electricity and comparing this with the price in the previous period, they ascertain whether electricity is over- or undervalued and decide whether to sell or buy the asset respectively. Whether they made a correct forecast about the future price and hence whether they received a positive return on their investment depends on the eventual future price. To determine whether their forecasting strategy is successful, the return on the fundamentalist's strategy will be compared with the actual change of the future price in comparison with the current price, hence the electricity price return. This reasoning is also applied in determining the performance of the chartist strategy with the only difference that chartists base buying and selling decision on price trends and not on the fundamental value.

To determine the performance of both strategies, one should compare the returns predicted by choosing a certain strategy, with the return generated by the change in electricity prices between the previous and the current period on the electricity market. Based on the forecasting performance agents choose a strategy. Therefore the less forecasting errors a strategy generates, the more investors will choose to follow this strategy. Hence, to calculate the forecasting errors, the following formula is used:

$$\pi^{f}{}_{t} = \sum_{k=1}^{K} \left(D^{f}{}_{t-k-1} - \Delta P_{t-k} \right)^{2} \tag{3}$$

$$\pi^{c}{}_{t} = \sum_{k=1}^{K} \left(D^{c}{}_{t-k-1} - \Delta P_{t-k} \right)^{2} \tag{4}$$

In these formulas $\pi^{f}{}_{t}$ represents the sum of the squared forecasting errors generated by the fundamentalist strategy in the previous k > 0 days. The forecasted return on electricity generated by applying the fundamentalist strategy in the period t - k -1 will be compared with the actual return on electricity in period t – k, to eventually, in period t, identify the forecasting error of the fundamentalists. Therefore $\pi^{f}{}_{t}$ is a performance measure of the fundamentalists strategy and $\pi^{c}{}_{t}$ represents the performance measure of the chartists approach.

Based on these forecasting errors, investors choose a strategy. As a result, the fraction of fundamentalists active in the market depends on the relative performance of the two strategies compared to each other. This is illustrated by the following formula:

$$w_t = 1 \Big/ \left[1 + \exp\left(\gamma \left[\frac{\pi^c{}_t - \pi^f{}_t}{\pi^c{}_t + \pi^f{}_t} \right] \right) \right] \qquad (5)$$

Where w_t is the fraction of chartists in the market and 1-w_t is the fraction of investors in the market which apply the fundamentalist strategy at time t, and therefore this formula can be seen as a switching mechanism. Based on both strategy's forecasting errors an investor chooses which approach to apply the next period. The parameter, γ, demonstrates the response of the investors to these forecasting errors and therefore it can be seen as a parameter for the intensity of choice. Hence, when a strategy – fundamentalist's or chartist's – made a correct prediction in the previous period about the future price then this strategy will be chosen more often the next period and therefore the weight of this strategy increases. When the fundamentalists strategy performed well in the previous periods the weight of this agent's group will increase relative to the weight of chartists. How fast agents respond to a strategy's predictive power is represented by γ .When $\gamma = \infty$ investors respond immediately to the performance of a strategy. Therefore, when the fundamentalists predicted the correct expected price in the previous period, all investors will switch to this strategy. When $\gamma = 0$ the agents do not respond to the forecasting power of the strategies and therefore their weights are equal in the market; $w_t = 0{,}5$.

Hence, because there are two types of investors active in the market, the total demand for electricity is given by,

$$D_t = w_t D^f{}_t + (1 - w_t) D^c{}_t \qquad (6)$$

Where the total demand in the market for electricity is determined by the relative demand of fundamentalists and the relative demand of chartists. Because there are only two groups of traders active in the market their relative weights (w_t) add up to 1. For example when there are no chartists active in the market, w_t is zero and 1-w_t is 1, which means that total demand is completely determined by the electricity demand of fundamentalists.

Finally, changes in the electricity prices are a function of the demand for electricity derivatives and a noise term.

$$P_{t+1} = P_t + \theta D_t + \varepsilon_t \qquad (7)$$

Where θ governs market frictions as a positive price adjustment parameter and in which ε_t is a random noise term.

We assume that there is no excess supply of financial electricity products in the market. This means that the amount of future contracts available is constant over time and that they will be divided among fundamentalists and chartists. Logically, when more speculators will choose for the fundamentalist strategy, the amount of chartists in the market will decrease with the same pace.

Putting all these formulas together and rewriting it gives the following equations which will be used to estimate the model.

$$\left.\begin{aligned}
&\Delta P_{t+1} = w_t\left(\alpha\left(P_t - F_t\right)\right) + (1-w_t)\left(\sum_{i=0}^{I}\left[\beta_i\left(P_{t-i} - P_{t-i-1}\right)\right]\right) + \varepsilon_t \\
&w_t = 1/\left[1 + \exp\left(\gamma\left[\frac{\pi^f{}_t - \pi^c{}_t}{\pi^f{}_t + \pi^c{}_t}\right]\right)\right] \\
&\pi^f{}_t = \sum_{k=1}^{K}\left[\alpha(P_{t-k} - F_{t-k}) - \Delta P_{t-k+1}\right]^2 \\
&\pi^c{}_t = \sum_{k=1}^{K}\left[\beta(P_{t-k} - P_{t-k-1}) - \Delta P_{t-k+1}\right]^2
\end{aligned}\right\} \qquad (8)$$

In which, $\alpha = \theta\alpha^f b^f$ represents the price impact of the fundamentalists and $\beta = \theta\beta^c b^c$ represents the price impact of investors applying the chartist analysis.

In the next section the data and methodology used to estimate this HAM will be described and the results will be discussed.

7 - Data and Methodology

To test whether there are various types of agents trading on the electricity market and what kind of influence they have on the price of electricity, the above described HAM will be estimated using data from three different European energy exchanges, namely the APX, the European Energy Exchange (EEX) and the Nordpool exchange. The APX is the an energy exchange with electricity market operations in the Netherlands and the United Kingdom[1]. The EEX comprises the Central part of Europe - Germany, Austria, Switzerland and France - with its energy exchange[2]. Nordpool is the North European energy exchange, covering Norway, Sweden, Finland and Denmark[3].

To test the model day-ahead market prices were used from the above mentioned exchanges. Day-head prices implies that agents can trade upon electricity 24 hours before delivery. In this model we will refer to these day-ahead prices as spot prices. The daily spot prices of the following periods are used to estimate the model: APX and EEX 01/01/2003 to 11/23/2009 and Nordpool 12/29/2003 to 11/24/2009.

Besides the spot prices, the one year, two year, and three year futures contracts of these three markets were empirically tested. These contracts were traded for a year and the delivery of electricity took place during 2008. Hence, the one-year futures were traded from January 2007 to December 2007 and then the electricity were to be delivered between January 2008 and December 2008. The two-year future contracts were only traded upon for one year, during 2006, and the delivery of electricity again took place between January 2008 and December 2008. Finally, the three-year electricity futures were traded during the year 2005 and promised delivery of electricity during the year 2008. To estimate the model daily spot and future prices were used. Because the APX states future bid and ask prices, the average of these two prices are used as the daily future price. EEX and Nordpool report only one daily future price and therefore this value is used to estimate the model.

The spot prices are traded every day of the week, as opposed to the future contracts which are traded upon only during working days. The used prices represent the average price over the day of one megawatt of electricity per hour.

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1 : http://www.apxgroup.com/index.php?id=10 (visited at April 13th 2010)
2 : http://www.eex.com/en/document/72732/E_Company_2010.pdf (visited at April 13th 2010)
3 : http://www.nordpool.com/en/asa/Markets/
http://www.nordpoolspot.com/upload/Nordic%20power%20market/The%20Nordic%20Electricity%20Exchange%20Nord%20Pool%20Spot%20and%20the%20Nordic%20Model%20for%20a%20Liberalised%20Electricity%20Market.pdf (visited at April 13th 2010)

Table 1a, 1b and 1c in appendix A show the descriptive statistics of log price, log fundamental value, the misalignment between the log price and log fundamental value and the log returns for all three markets. Looking at the standard deviation of the log price is becomes clear that the spot prices reveal a lot more volatility than the future contracts. This makes sense because the spot prices used are day-ahead prices. When one wants to buy or sell electricity as a commodity or as a financial product there are three types of markets available to them: the futures market, the day-ahead market, and another very short term spot market. In the day-ahead market one can buy or sell electricity one day before delivery. The realized price in that market is what is we call here the spot price. Companies and traders who need electricity can buy and sell the required amount of electricity they expect to be needing in future periods in the derivatives market by buying and selling futures. However, when they unexpectedly need more or less electricity the next day, they will trade in the day-ahead market. Unexpected buying and selling decisions always lead to more volatility in a market. Moreover, the non-storability character of electricity adds volatility to the prices. Figures 1a, 1b and 1c in appendix B display the movement in the electricity price over time for the APX, EEX and Nordpool exchange, respectively.

Except for the APX spot prices, all contracts and spot prices display on average a positive return. Therefore, on average it was profitable to invest in electricity. Furthermore, the misalignment between the price of electricity and its fundamental value is for all contracts and spot prices positive, which means that on average electricity was priced above its fundamental value in the market, hence it was overpriced. The kurtosis of the misalignment between the price of electricity and its fundamental value, and the return are larger than 3. This indicates excess kurtosis and means that these variables have a peaked distribution and show signs of fat tails.

The estimations of this model are done by using quasi-maximum likelihood. This statistical method is based on the maximum likelihood method but with the alteration that residuals are assumed to be drawn from a normal distribution.

The optimal lag length, k, depicted in formulas 3 and 4 is empirically determined by applying the Box-Jenkins method and is set equal to 2 periods. Hence, speculators review the performance of both strategies for the previous two days and then determine which strategy to apply.

The next section discusses the results of the empirical test. The test is twofold. First, the model where the traders do not yet have the opportunity to switch to the other strategy will be estimated. Thereafter the switching mechanism will be added to the model.

8 - Results

8.1 In-sample

To find out whether there are different types of agents, fundamentalists and chartists, actively trading in the electricity market and to examine their effect on electricity prices, the above described model will be estimated. The test is twofold: the model will be tested with constant as well as time-varying weights. To execute the former mentioned model the switching parameter, γ, will be set equal to zero. Consequently, the relative weight of the chartists, w_t, is equal to 0,5 and as a result of that, the relative weight of the chartists will be equal to 0,5 as well. Hence, in the model without switching the market consists for fifty percent of fundamentalist agents and for fifty percent of chartists. Thereafter the model with the time-varying weights will be tested, which is named the switching model. The in-sample estimation results of the static and switching models are presented in the following table.

Table 2: In-sample estimation results

	APX		EEX		Nordpool	
	Static	**Switching**	**Static**	**Switching**	**Static**	**Switching**
	Fundamentalists					
Y1	-0.4839	0.1100**	-0.6938**	-0.3133***	-0.5113	0.1762
	(0.1251)	(0.0167)	(0.0486)	(0.0013)	(0.1797)	(0.1796)
Y2	0.0738	-0.0054	-0.6398	-0.3879***	0.2500	0.2915***
	(0.8343)	(0.9646)	(0.1377)	(0.0000)	(0.5085)	(0.0027)
Y3	0.0379	-0.4559	0.7040	0.2211	0.0853	0.6492***
	(0.8786)	(0.1225)	(0.1398)	(0.4052)	(0.8486)	(0.0000)
Spot	-1.5363***	-0.8966***	-1.4523***	-0.9447***	-1.1483***	-0.6390***
	(0.0000)	(0.0000)	((0.0000)	(0.0000)	(0.0000)	(0.0000)
	Chartists					
Y1	0.5764**	0.2374***	0.4721	0.2120***	0.2563	-0.2012***
	(0.0114)	(0.0004)	(0.0615)	(0.0012)	(0.3652)	(0.0051)
Y2	0.2337	0.3050***	0.0397	0.1560	0.3872	0.3343***
	(0.4017)	(0.0000)	(0.8953)	(0.2120)	(0.2195)	(0.0000)
Y3	0.9007***	1.0573***	-0.7605**	-0.2235***	-0.1177	-0.1938*
	(0.0000)	(0.0000)	(0.0276)	(0.0000)	(0.6933)	(0.0595)
Spot	0.6730***	0.1990***	0.5418***	0.2018***	0.4729***	0.0598***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)
	Switching					
Y1	NA	1028.1210	NA	413.8567	NA	431.7505
		(0.9308)		(0.8212)		(0.8971)
Y2	NA	-49.5183	NA	1993.1630	NA	-1204.0400
		(0.6585)		(0.9300)		(0.9425)
Y3	NA	-0.9207**	NA	78.0689	NA	1548.2110
		(0.0120)		(0.7707)		(0.9525)
Spot	NA	8.2465***	NA	14.1324***	NA	23.4145***
		(0.0000)		(0.0000)		(0.0000)

Notes: Table 2 presents the estimation results of the model given by equation 8 The results are divided into the three markets, APX, EEX and the Nordpool exchange. Each of these markets is tested with a non-switching and a switching model. The results are presented per futures contract (1 year, 2 year and 3 year contracts) and spot prices (day-ahead market). Lastly, the table is subdivided into the results of the two different traders and the intensity of choice, named switching here. The p-values of the coefficients are in parentheses and *, ** and *** denotes the level of significance of respectively 10 %, 5 % and 1 %.

It is expected that fundamentalists have a stabilizing effect on the market and therefore their estimated coefficient, α, in formula 8, is expected to be negative. Because fundamentalists base their buying and selling decisions on the deviation of the current price with the fundamental value of electricity, the latter value is needed. However, this value is not publicly available and therefore it needs to be estimated. Because electricity prices mean-revert, a moving average can be used to approximate the fundamental value of electricity. The lag length of the moving average is optimized outside the model and is pinpointed at 3 days. This means that fundamentalists use the electricity prices of the three previous days to determine the fundamental value of electricity.

When looking at the outcomes of the static model, we see that that the coefficients of the one-year futures and spot prices for the fundamentalists have the correct sign. The two year and three year contracts display, except for the EEX two year future, positive coefficients, which is not in line with the theory. Testing the significance of these results we see that only the spot prices are significant at a 1 % level and the 1 year forward contract of the EEX market is significant at a 5 % level.

Looking at the chartists we can see that these coefficients have, except for the 3 year future contract of the EEX and Nordpool market, positive signs. This is in line with the expectations: chartists extrapolate previous price movements and therefore they have a destabilizing effect on the market. To determine the amount of previous returns chartists will include in their analysis, a test which assesses the autocorrelation between electricity price returns is executed. This test reveals that chartists determine the price trend of electricity prices on the return of one period back in time. Hence, when the previous return, at time t-1, on electricity was positive, chartists expect the return to be positive again this period, at time t. This test, as well as the test determining the lag length of the moving average, are computed outside the model. This method is conform reality because we deal with boundedly rational agents who are incapable of overseeing the entire model. Again, the spot price estimations display significant results at a 1 % level. Furthermore, non of the two year contracts as well as the Nordpool future contracts show significant results.

By allowing the fundamentalists and chartists to switch between strategies the model becomes a lot more realistic. In this new setting the intensity of choice, γ, is not set at zero, but will be estimated by the model. When looking at the coefficients estimated by the switching model, it becomes clear that the fundamentalist parameters still show a rather diverse pattern. The APX 1-year future contract and 2- and 3-year future contracts of the Nordpool exchange display significant positive coefficients, which is contrary to what is expected. On the other hand, the coefficients of the spot prices significantly show that fundamentalists have a stabilizing effect on the market.

When allowing agents to switch between strategies, the chartist coefficients show almost the same outcomes with the switching models as with the static model. All the coefficients have a positive sign, except for the EEX 3-year future and Nordpool 1- and 3-year future contracts. Furthermore, the coefficients of the spot prices have positive signs and are significant at a 1 % level as well as the coefficients of the APX market. This indicates that chartists have a destabilizing effect on the market.

This more realistic model allows agents to switch between strategies because the parameter, γ, the intensity of choice, is not fixed at a value of zero - which results in a market which is for fifty percent dominated by fundamentalist and for the other fifty percent governed by chartists – but is allowed to be estimated by the model. A value of zero indicates status quo bias which means that traders will refuse to change strategies. When $\gamma = \infty$, traders will react immediately to the profitability of their forecasting strategy. When their applied strategy failed to estimate the actual price change, they will switch immediately to the other strategy. Therefore, the estimation of this switching mechanism is based on the errors the strategy makes in forecasting the future price of electricity and determines the relative number of fundamentalists and chartists in the market. The Box-Jenkins method is used to determine how many periods the traders will evaluate to determine whether to switch to the other strategy or not. Fundamentalists and chartists base their decision to stick to their strategy or to switch to another rule, on the performance of their chosen strategies of the previous two trading days.

The estimation results of the intensity of choice are also presented in table 1. The coefficients show a rather diverge pattern, ranging from values between –1204.04 to 1993.16. The spot prices show positive and significant values for the intensity of choice. This implies that according to equation 5 fundamentalists and chartists switch between strategies and will choose the strategy making the least forecasting errors and therefore the highest profit. Apart from the positive values for the intensity of choice for the spot prices, there are three future contracts which display negative values for this coefficient. Because the value is not equal to zero, this negative value implies that agents do react to the forecasting errors of their strategy. However, when their chosen strategy displays a forecasting error they will stick to the same strategy and will not switch to the better performing trading strategy. Moreover, a negative value for the intensity of choice implies that agents will switch to the strategy with the highest forecasting errors and therefore the worst performance, which is not in line with the theory nor common sense.

To see whether the switching model is more capable of explaining the volatility in electricity prices and the behaviour of agents, a loglikelihood test is applied. The results are presented in table 3.

Table 3: In-sample statistics and results of the loglikelihood ratio test

	APX		EEX		Nordpool	
	Static	Switching	Static	Switching	Static	Switching
			Observations			
Y1	246	246	246	246	245	245
Y2	248	248	247	247	248	248
Y3	251	251	250	250	195	195
Spot	2516	2516	2516	2516	2154	2154
			Loglikelihood			
Y1	817.9013	819.3855	827.4292	832.4703	735.1902	737.0332
Y2	829.7951	831.7367	711.9658	715.4989	755.982	757.2461
Y3	918.1226	921.5233	824.8765	825.4868	612.4603	620.7301
Spot	-693.5952	-608.8467	-623.399	-457.5865	2077.83	2135.144
			2ΔLoglikelihood			
Y1	NA	2.9684*	NA	10.0822***	NA	3.6860*
Y2	NA	3.8832**	NA	7.0662***	NA	2.5282
Y3	NA	6.8014***	NA	1.2206	NA	16.5396***
Spot	NA	169.4970***	NA	331.6250***	NA	114.6280***

Notes: Table 3 presents the number of observations as well as the results of the loglikelihood test used for the in-sample test. 2Δloglikelikhood represents the outcomes of the loglikelihood ratio test for added value of the switching mechanism. The p-values of the coefficients are in parentheses and *, ** and *** denotes the level of significance of respectively 10 %, 5 % and 1 %.

The outcomes of the likelihood ratio test reveal that after introducing the possibility to switch between strategies, in general, the statistic plausibility of the model is increased significantly. Apart from the 3-year EEX future and 2-year Nordpool contract, including the switching mechanism adds value to the model which is denoted at the 0.10, 0.05 and even 0.01 significance level. Again, the explanatory power of the switching model for the spot prices increases at a significance level of 0.01

8.2 Weights

In table 4, presented in appendix c the descriptive statistics of the weights are presented. The weights give information about the behaviour of the traders in the electricity market because it indicates relatively the percentage of traders that implemented the chartist strategy. Remember that the relative amount of fundamentalists active in the market is given by $1 - w_t$. The median values range between zero and one. Except for the 3-year EEX and 2-year Nordpool futures, the median values are higher than the mean values which implies a positively skewed distribution. The minimum and maximum values in the table clearly show that there is a lot of variation, because the values range between zero and one. That means that at different moments in time there are more chartists in the market than fundamentalists and vice versa. The variation in weights is clearly visible in figurea 2a, 2b, and 2c in appendix D. For example, one can see that on some days the market is entirely dominated by chartists and the next day it may be dominated by fundamentalists, indicated by w_t is zero.

The relationship between the forecasting errors, weights and the intensity of choice can be clarified with a graph. When putting w_t, on the y-axis and the relative difference between the fundamentalists' forecasting error and the forecasting error of the chartists on the x-axis, we expect that the data will show a s-shaped curve. Remember that w_t is the relative weight of the chartists in the market and that 1-w_t represents the weight of fundamentalists in the market. Thus, when the chartist strategy successfully predicts expected returns and, hence its forecasting errors are low, we expect that relatively more agents will switch to this strategy and less will choose the fundamentalists strategy. The same reasoning holds for the fundamentalists. Furthermore, when both strategy display relatively few errors, and therefore the value on the x-axis is zero, speculators will be approximately evenly divided among both strategies, hence w_t is 0.5. This is the point where the curve is mirrored. The graphs are shown in figures 3a, 3b and 3c in appendix E for the APX, EEX and Nordpool exchange respectively.

When the intensity of choice is large and positive, agents will react to the forecasting errors and will switch to the most profitable strategy. However, when the intensity of choice is negative, agents react contradictory and will switch to the least profitable strategy. This is clearly shown in figures 3a and 3c where the graph of the 2-year future contracts of the APX and Nordpool exchange are displayed and where the s-shaped curve is exactly mirrored due to the negative value of the intensity of choice coefficient. Therefore, the weight of chartists in the market is high when the forecasting error of the chartist strategy is high. Furthermore, a value close to zero for the intensity of choice coefficient indicates status quo bias. This is shown in figure 3a which displays the 3-year future contract of the APX exchange and where you can see a straight line in stead of a s-curve. With a value of -0.9207 for the switching coefficient agents react only minor to the forecasting errors. Furthermore, due to the negative sign agents will switch to the strategy with the most forecasting errors. The graphs of the spot prices, presented in figures 3a, 3b and 3c, clearly show the expected s-shaped curve where low forecasting errors for the chartist strategy will attract more agents and therefore the chartist's weight will increase.

To examine the relationship between the weights of the different markets over the different contracts and spot prices we will estimate the correlation between the weights of the different exchanges. The results are presented in table 5, in appendix F. Looking at the 1-year future contracts, the APX and EEX show a positive correlation. This means that when more speculators in the APX market will choose for the chartists strategy, then traders on the EEX exchange will choose for the chartist strategy as well. The correlation between the Nordpool market and APX and EEX exchange is both negative and rather small, which means when traders in the Nordpool move to the chartists strategy, traders in the APX and EEX will move to the fundamentalist strategy. Looking at the 2-year contracts we see a

different pattern. Again the correlation between the APX and EEX exchanges is the strongest, however now its negative. The correlation between the EEX and Nordpool exchange is negative again, but near zero, which means that there is not a clear linear relationship visible. The relationship between the APX and Nordpool exchange is negative but low, for the 2-year contract.
The 3-year contract displays the same pattern as the correlation between the markets with the 1-year future contracts. The APX and EEX market show positive correlation in the weights. Again, as the weight of chartists increases in the APX market, the weight of chartists in the EEX market will increase as well. However, when the weights of chartists active at the Nordpool exchange increases, their weight will decrease in the APX and EEX level. Which means that in the latter mentioned markets, the weight of fundamentalists will increase.
Finally, looking at the correlation in weights over the different markets by speculating on spot prices leads to the following conclusions. Again, there is a positive correlation of 0.55 between the APX and EEX exchanges, which is quite strong. On the other hand, the correlation between Nordpool weights and APX and EEX weights is near zero and one could conclude that there is not a linear relationship between the weights in these markets.

The correlation between the different contracts and the spot price within the same markets is rather low. But this might have been instigated by the fact that, although the contracts all mature in 2008, each of them is traded in a different year in which traders have different expectations and make different choices about their investment strategies. Therefore the weights do not show clear correlation.

It is clear that traders in the Nordpool exchange do not always have the same expectations or behave the same as traders in the APX and EEX exchange do. The latter two market display a more pronounced linear relationship with each other than they do with the Nordpool exchange. Furthermore, the negative values of the correlation coefficients might be caused by the negative value of the intensity of choice coefficient. However, this relationship not entirely clear. Looking at the correlations of the weights within the markets, we see that the APX and Nordpool market show more negative coefficients than the EEX shows. This might have been instigated by the fact that within the APX market two contracts and within the Nordpool exchange one contract displays a negative intensity of choice coefficient, which means that speculators will choose the strategy which produces the most errors.

To take a closer look at the future contracts and the behaviour of the traders investing in these futures we will examine the relationship between the weights and the time to maturity of the futures contract. The results of this regression are presented in table 6.

Table 6: Results of regression between weights and the contract's time to maturity

	APX		EEX		Nordpool	
	slope	**constant**	**slope**	**constant**	**slope**	**constant**
Y1	0.000816*	0.450885***	5.10E-05	0.497958***	-1.57E-05	0.516480***
	(0.0578)	(0.0000)	(0.9072)	(0.0000)	(0.9714)	(0.0000)
Y2	-0.000418	0.568539***	0.001118***	0.385290***	-0.000336	0.472321***
	(0.2840)	(0.0000)	(0.0096)	(0.0000)	(0.4303)	(0.0000)
Y3	0.000213**	0.490729***	7.62E-05	0.475239***	-0.000816	0.709690***
	(0.0315)	(0.0000)	(0.8527)	(0.0000)	(0.1702)	(0.0000)

Notes: Table 6 presents the results of the regression between the weights and maturity of the contract. The p-values of the coefficients are in parentheses and *, ** and *** denotes the level of significance of respectively 10 %, 5 % and 1 %.

In this table the slope represents the relationship between the time to maturity and the weights. Therefore a positive coefficient for the slope means that when the contract is still far away from maturity there are more chartists trading upon this future than when the contract reaches maturity. Hence, a positive slope means that when the contract reaches maturity more traders will become a fundamentalist and the amount of chartists in the market will decrease. The slope represents the change in weights per day until maturity. The coefficient 'constant' represents the mean weight and therefore it makes sense that this coefficient has a value somewhere around 0.5.

The table shows a rather diverse pattern of results. The Nordpool futures all have a negative slope, which means that when the contract reaches maturity more traders will become a chartist. However, the coefficients are not significant. The APX and EEX contracts show mainly positive coefficients and are significant for the APX 1- and 3-year contracts and the EEX 2-year contract. In these markets, when the contract reaches maturity more traders will become fundamentalist and less will become chartist.

Besides this extra understanding about the behaviour of speculators investing in futures, we can also gain some knowledge about the weight of chartists and the returns per day of the week when looking at the spot prices.

By using day-of-the-week dummies we can find out whether and on what days of the week the return on electricity is higher and on what days of the week there are relatively more chartists trading than fundamentalists in the spot market, in which the latter is represented by a high value for w_t. The results of these regressions are presented in the following table.

Table 7: Results weight and returns per day of the week in the spot market

	w			dlog(p)		
	APX	**EEX**	**Nordpool**	**APX**	**EEX**	**Nordpool**
Monday	0.31794***	0.21671***	0.77441***	0.07033***	0.0770***	0.1247***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Tuesday	0.2015***	0.1621***	0.2898***	-0.0177	-0.0021	0.0047
	(0.0000)	(0.0000)	(0.0000)	(0.1703)	(0.8619)	(0.2803)
Wednesday	0.7582***	0.7705***	0.2538***	-0.0157	-0.0285**	0.0019
	(0.0000)	(0.0000)	(0.0000)	(0.2244)	(0.0172)	(0.6645)
Thursday	0.7128***	0.7143***	0.6168***	-0.0633***	-0.0615***	-0.0092**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0371)
Friday	0.5561***	0.4652***	0.7030***	-0.2162***	-0.2209***	-0.0219***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Saturday	0.5843***	0.6155***	0.6230***	-0.2495***	-0.2632***	-0.0549***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sunday	0.8340***	0.8872***	0.6303***	0.4915***	0.4995***	-0.0448***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes: Table 7 presents the height of the weights and returns per day of the week in the spot market by using day-of-the-week dummies. The table is divided into the outputs of the weight regressions and the return regressions . Furthermore, the results are presented per exchange. The p-values of the coefficients are in parentheses and *, ** and *** denotes the level of significance of respectively 10 %, 5 % and 1 %.

Remember that the weights give information about the behaviour of the traders in the electricity market because it indicates relatively the percentage of traders that implemented the chartist strategy. Remember that the relative amount of fundamentalists active in the market is given by 1 – w_t. The coefficients represent the average weights of chartists on a specific day. When on certain day in the table, the coefficient is 0.5, this means that, on average on that day, the market is dominated for 50 percent by fundamentalist and for 50 percent by chartists. The APX and EEX market show a similar pattern: on Monday and Tuesday, there are on average more fundamentalists than chartists in the spot market. On Wednesday, Thursday, Saturday and Sunday, there are on average more chartists than fundamentalists in the spot market. The two markets differ on Friday: on the APX exchange there are on average more chartists and on the EEX exchange there are on average more fundamentalists in the spot market. However, these markets display a similar decision making process. On Sunday the weight of chartists is highest. Then, on Monday more traders will choose the fundamentalist strategy, and this will increase even more on Tuesday. Wednesday is a turning point, where on Tuesday there were on average more fundamentalists in the spot market, on Wednesday there are on average more chartists than fundamentalists in the spot market. On Thursday and Friday the weight of chartists decreases but will rise again on Saturday and even more on Sunday. The Nordpool exchange shows a different pattern. Not on Sunday, but on Monday, on average the weight of chartists in the spot market is highest. This means that on all the other days of the week there are less chartists trading in the Scandinavian spot market. On Monday, there are more fundamentalists than chartists investing in the market, as well as Wednesday. This changes on Thursday, where on average the weight of chartists is higher than the weight of fundamentalists in the market. On Friday, the weights of chartists rises and it will drop a little bit on Saturday. However, there are still, as well as on Sunday, more chartists in the market than fundamentalists, on average.

Looking at the average returns per day, the APX and EEX show again a similar pattern. On average, Sunday displays the highest return of the week. On Monday the return is a lot smaller, but still positive, contrary to the returns on Tuesday, Wednesday, Thursday, Friday and Saturday which are negative on average. The Nordpool market shows, on average, the highest return in the spot market on Monday. Tuesday and Wednesday display positive returns as well, but they are a lot smaller and not significant. In the Nordpool spot exchange one generates on average a negative return on Thursday, Friday, Saturday and Sunday.

It is remarkable to see that in all three markets, the day that displays the highest value for the weights, which in Sunday when looking at the APX and EEX Market and Monday at the Nordpool exchange, the average return is the highest as well compared to the other days of the week. However, there is not a relationship visible that when the level of chartists in the market increases, the return on the spot prices increases as well.

To test whether the daily coefficients differ significantly, a Wald test is executed. All estimated coefficients differ significantly except for the Saturday and Sunday weights as well as return coefficients of the Nordpool exchange on these days. This is quite logic because these days are in the weekend and electricity prices on week days and on weekend days show dissimilar characteristics from each other. .

As already perceived in the weight correlation table, there exists a stronger relationship between the APX and EEX exchange than both these market show to have with the Nordpool exchange.

9 - Conclusion and recommendations

In this thesis we studied the presence of heterogeneous agents in the electricity market and whether their trading is of influence on electricity prices. To test this we used a model that is based on the HAM of Ter Ellen and Zwinkels (2010). A distinction has been made between two types of speculators: fundamentalists and chartists. Both of these groups of traders buy and sell electricity in the financial market with the ultimate aim of making a profit. However, their decision making process, whether to buy or sell electricity, differs due to different expectations. Fundamentalists expect the price the mean-revert to its fundamental value and therefore these traders have a stabilizing effect on the market. The other group of traders, chartists, trade upon price trends and have a destabilizing effect on the market. This HAM allows fundamentalists and chartists to switch between the different forecasting strategies. Whether an agent will switch or not is based on the past profitability of both strategies.

Using prices from 1-, 2-, and 3-year electricity futures which promises delivery in 2008 and which are traded on the APX, EEX and Nordpool exchange, as well as spot prices of electricity traded 24 hours before delivery in these three European markets as well, the estimated results indicate that there are agents with heterogeneous believes trading in these markets. Especially the presence of heterogeneous agents in the spot markets is remarkable and one might believe that these different agents at least partially determine the spot price of electricity. Fundamentalists have a stabilizing effect on the spot market because their trading results in the price returning to its true or fundamental value. On the other hand, due to chartists, who extrapolate previous prices trends into the future, the price of electricity will move further away from its fundamental value and therefore they have a destabilizing effect on the spot market.

Looking at the correlation of the weights between the different markets and contracts, we can conclude that there exists a linear relationship between the behaviour of traders in the APX exchange and the EEX exchange. On average, when traders in the APX choose to move to the chartist strategy, investors trading on the EEX exchange will choose to implement this destabilizing strategy as well.

When taking a closer look at the electricity future contracts, by examining the behaviour of traders during the expiration of the contract, we see that as the contract reaches maturity more traders will become a fundamentalist in the APX and EEX market, on average. While more investors active on the Nordpool exchange will become a chartist, on average.

The spot prices were used to take a closer look at the behaviour of traders during the week. We identified that there are certain days whereupon, on average more chartists than fundamentalists trade and vice versa. Furthermore, we identified which days in the different markets had the highest returns on average. Again the APX en EEX show a similar pattern concerning weights as well as returns. For example, in both markets, the level of chartists is highest on Sunday and the movement of traders between strategies is quite similar. Therefore, these markets display quite an akin decision making process.

Why the APX and EEX show very similar results and tend to move together and seem to have only a minor relationship with the Nordpool exchange is not entirely clear. One should to further research to find the exact cause of this observation.

Although the presented model is already a lot more realistic than the financial models which assume homogeneous rational agents, it is still highly stylized. Besides the fact that traders are not purely classifiable into two groups, there are a lot of other factors influencing the prices of electricity as well which are not incorporated into the model. The electricity market is a market with strange characteristics due to the non-storability feature, and therefore a very interesting field for future research.

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APPENDIX A Descriptive statistics price and fundamental value

Table 1a: Descriptive statistics log price, log fundamental value, misalignment between log price and log fundamental value, and return of the APX exchange

	APX															
	Y1				Y2				Y3				Spot			
	P	**F**	**P - F**	**ΔP**	**P**	**F**	**P - F**	**ΔP**	**P**	**F**	**P - F**	**ΔP**	**P**	**F**	**P - F**	**ΔP**
Mean	4.0986	4.0981	0.0005	0.0005	4.1381	4.1379	0.0002	0.0001	3.8245	3.8232	0.0013	0.0013	3.7703	3.7703	0.0001	0.0000
Median	4.1063	4.1069	0.0009	0.0008	4.1329	4.1343	0.0000	-0.0001	3.8841	3.8869	0.0006	0.0007	3.7257	3.7218	-0.0072	-0.0240
Maximum	4.1894	4.1869	0.0259	0.0316	4.2308	4.2293	0.0301	0.0541	3.9917	3.9874	0.0312	0.0324	6.4928	6.2868	2.2444	3.5389
Minimum	3.9342	3.9412	-0.0274	-0.0318	4.0655	4.0543	-0.0334	-0.0371	3.6326	3.6337	-0.0308	-0.0344	2.3532	2.6134	-1.5066	-2.5334
Std. Dev.	0.0535	0.0529	0.0069	0.0088	0.0359	0.0357	0.0068	0.0086	0.1241	0.1241	0.0062	0.0071	0.4599	0.4070	0.2340	0.3331
Skewness	-0.6457	-0.6354	-0.2096	-0.3264	0.3682	0.3264	0.0193	0.7287	-0.2975	-0.2870	0.7280	0.3755	0.4390	0.4486	0.4969	0.9140
Kurtosis	3.2279	3.1547	4.8729	5.1470	2.4786	2.4546	6.7564	9.9751	1.4895	1.4749	10.6234	10.3892	4.0142	3.1479	9.5010	12.6321
Jarque-Bera	17.63	16.80	37.76	51.61	8.41	7.48	145.82	524.68	27.57	27.77	629.96	576.92	188.66	86.66	4534.16	10076.55
Probability	0.0001	0.0002	0.0000	0.0000	0.0149	0.0238	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	1008.25	1008.12	0.12	0.13	1026.24	1026.20	0.04	0.03	959.94	959.62	0.33	0.33	9486.17	9486.04	0.13	-0.02
Sum Sq. Dev.	0.70	0.69	0.01	0.02	0.32	0.31	0.01	0.02	3.85	3.85	0.01	0.01	531.93	416.65	137.75	279.08
Obs.	246	246	246	246	248	248	248	248	251	251	251	251	2516	2516	2516	2516

Notes: Table 1a presents the descriptive statistics of the log price, log fundamental value, misalignment between log price and log fundamental value, and return of the APX exchange.

Table 1b: Descriptive statistics log price, log fundamental value, misalignment between log price and log fundamental value, and return of the EEX exchange

	EEX															
	Y1				Y2				Y3				Spot			
	P	F	P - F	ΔP	P	F	P - F	ΔP	P	F	P - F	ΔP	P	F	P - F	ΔP
Mean	4.0217	4.0212	0.0005	0.0005	4.0058	4.0053	0.0005	0.0006	3.6888	3.6879	0.0010	0.0009	3.6516	3.6515	0.0001	0.0001
Median	4.0181	4.0170	0.0009	0.0009	4.0117	4.0110	0.0003	0.0005	3.7051	3.7065	0.0008	0.0008	3.6194	3.6091	-0.0084	-0.0311
Maximum	4.1296	4.1178	0.0273	0.0324	4.0960	4.0947	0.0385	0.1021	3.8898	3.8491	0.0461	0.0642	5.7089	5.2425	1.6164	3.2676
Minimum	3.8928	3.8972	-0.0200	-0.0292	3.8898	3.8820	-0.0686	-0.1017	3.5721	3.5759	-0.0373	-0.0579	0.6931	2.0900	-1.9431	-2.6382
Std. Dev.	0.0516	0.0509	0.0063	0.0084	0.0365	0.0364	0.0094	0.0138	0.0726	0.0717	0.0063	0.0091	0.4488	0.3985	0.2246	0.3244
Skewness	0.0935	0.1104	-0.0726	-0.3061	-1.1368	-1.2332	-1.2225	0.4223	-0.0219	-0.0553	0.9382	-0.4560	-0.0787	0.2660	0.1414	0.9215
Kurtosis	2.7042	2.6742	4.1774	4.0840	5.2717	5.5238	15.9911	27.6145	1.8570	1.7466	19.7604	25.6598	4.3604	2.9883	7.4662	11.5785
Jarque-Bera	1.26	1.59	14.42	15.89	106.31	128.16	1798.42	6242.79	13.63	16.49	2962.85	5357.27	196.62	29.68	2099.49	8070.75
Probability	0.5338	0.4520	0.0007	0.0004	0.0000	0.0000	0.0000	0.0000	0.0011	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	989.34	989.22	0.12	0.12	989.43	989.32	0.12	0.15	922.21	921.97	0.24	0.22	9187.54	9187.19	0.36	0.28
Sum Sq. Dev.	0.65	0.64	0.01	0.02	0.33	0.33	0.02	0.05	1.31	1.28	0.01	0.02	506.48	399.42	126.84	264.64
Obs.	246	246	246	246	247	247	247	247	250	250	250	250	2516	2516	2516	2516

Notes: Table 1a presents the descriptive statistics of the log price, log fundamental value, misalignment between log price and log fundamental value, and return of the EEX exchange.

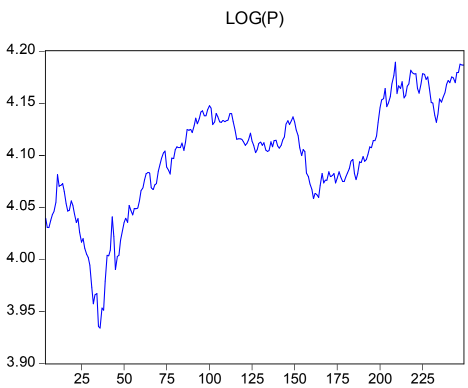
Table 1c: Descriptive statistics log price, log fundamental value, misalignment between log price and log fundamental value, and return of the Nordpool exchange

	Nordpool															
	Y1				Y2				Y3				Spot			
	P	F	P - F	ΔP	P	F	P - F	ΔP	P	F	P - F	ΔP	P	F	P - F	ΔP
Mean	3.8093	3.8084	0.0009	0.0009	3.7671	3.7666	0.0005	0.0005	3.5021	3.5012	0.0008	0.0009	3.5242	3.5242	0.0001	0.0001
Median	3.8044	3.8022	0.0013	0.0012	3.7682	3.7677	0.0000	0.0002	3.5308	3.5311	0.0013	0.0014	3.4860	3.4844	-0.0036	-0.0063
Maximum	4.0000	3.9902	0.0271	0.0345	3.8949	3.8884	0.0319	0.0550	3.5610	3.5596	0.0353	0.0453	4.3872	4.3659	0.5000	0.8365
Minimum	3.6350	3.6507	-0.0292	-0.0373	3.6109	3.6118	-0.0640	-0.0666	3.3810	3.3875	-0.0404	-0.0526	2.1748	2.2701	-0.4962	-0.6886
Std. Dev.	0.0930	0.0928	0.0089	0.0121	0.0638	0.0640	0.0099	0.0120	0.0537	0.0536	0.0077	0.0105	0.3202	0.3143	0.0670	0.0947
Skewness	0.2105	0.2256	-0.2055	-0.2830	-0.5342	-0.5699	-1.4898	-0.6869	-0.8475	-0.8293	-0.3948	-0.3741	-0.0987	-0.0040	0.2149	1.2720
Kurtosis	2.1796	2.1576	3.5836	3.4094	3.0419	3.0468	12.8035	10.2846	2.2678	2.1983	9.8270	9.3696	3.7244	3.4663	12.2801	18.3179
Jarque-Bera	8.68	9.32	5.20	4.98	11.81	13.45	1084.86	567.85	27.70	27.57	383.75	334.19	50.60	19.52	7745.79	21639.49
Probability	0.0130	0.0095	0.0742	0.0829	0.0027	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
Sum	933.29	933.06	0.23	0.23	934.24	934.11	0.13	0.13	682.91	682.74	0.17	0.17	7591.22	7591.04	0.18	0.20
Sum Sq. Dev.	2.11	2.10	0.02	0.04	1.00	1.01	0.02	0.04	0.56	0.56	0.01	0.02	220.70	212.68	9.67	19.31
Obs.	245	245	245	245	248	248	248	248	195	195	195	195	2154	2154	2154	2154

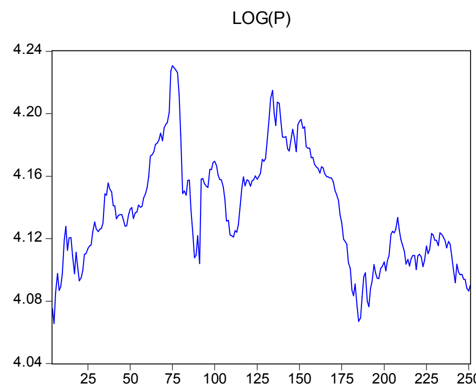
Notes: Table 1c presents the descriptive statistics of the log price, log fundamental value, misalignment between log price and log fundamental value, and return of the Nordpool exchange.

APPENDIX B Graphs log price

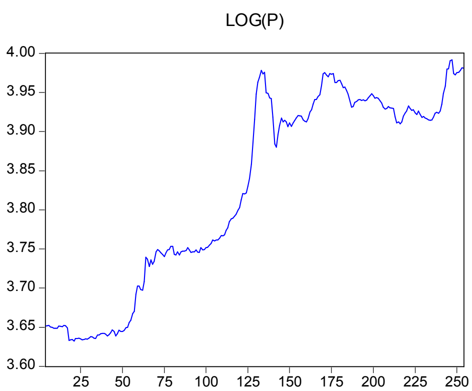
Figure 1a : Log prices APX exchange



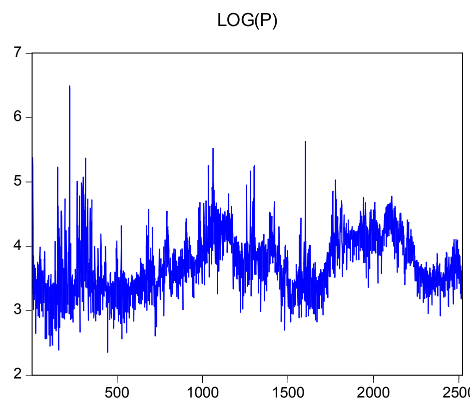
APX_Y1



APX_Y2



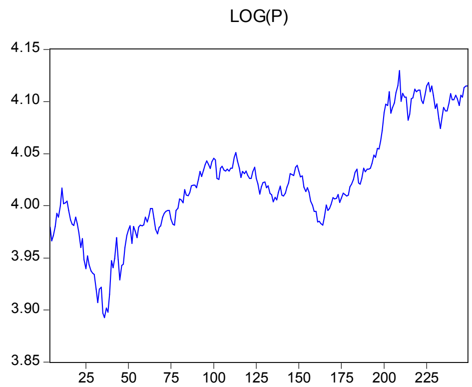
APX_Y3



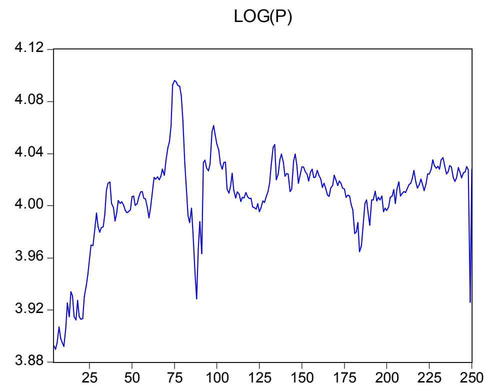
APX_spot

Notes: Log prices of 1-, 2-, and 3-year future contracts maturing in 2008 traded on the APX exchange. Log prices of electricity traded on the spot market of the APX exchange. Log prices are displayed on the y-axis and the trading days are displayed on the x-axis.

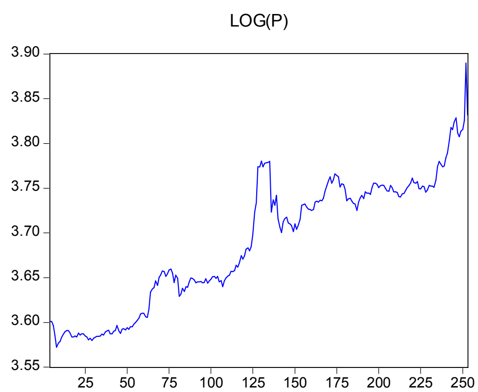
Figure 1b: Log prices EEX exchange



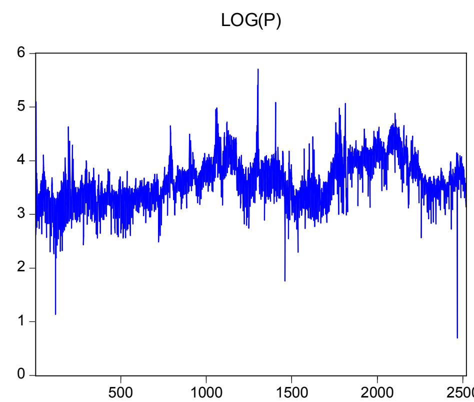
EEX_Y1



EEX_Y2



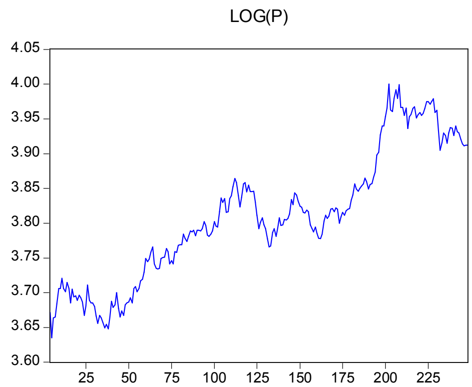
EEX_Y3



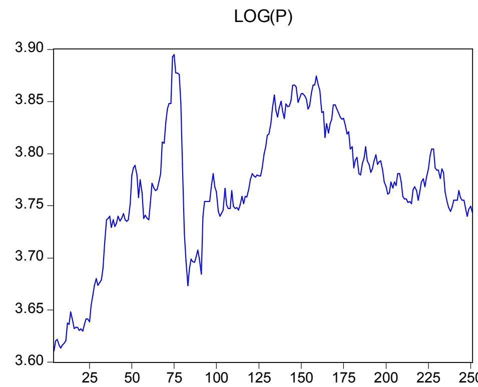
EEX_spot

Notes: Log prices of 1-, 2-, and 3-year future contracts maturing in 2008 traded on the EEX exchange. Log prices of electricity traded on the spot market of the EEX exchange. Log prices are displayed on the y-axis and the trading days are displayed on the x-axis.

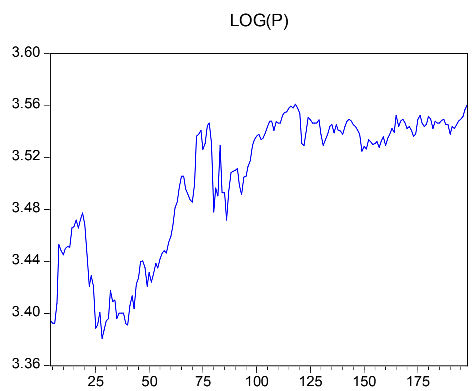
Figure 1c: Log prices Nordpool exchange



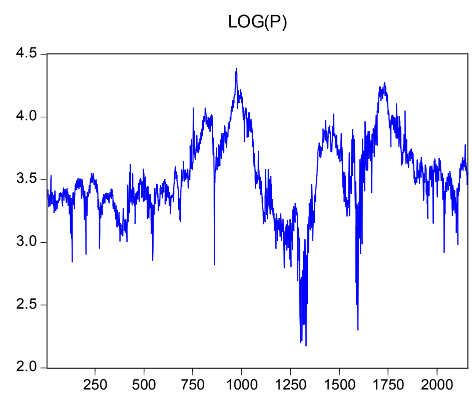
Nordpool_Y1



Nordpool_Y3



Nordpool_Y3



Nordpool_spot

Notes: Log prices of 1-, 2-, and 3-year future contracts maturing in 2008 traded on the Nordpool exchange. Log prices of electricity traded on the spot market of the Nordpool exchange. Log prices are displayed on the y-axis and the trading days are displayed on the x-axis.

APPENDIX C Descriptive statistics weights

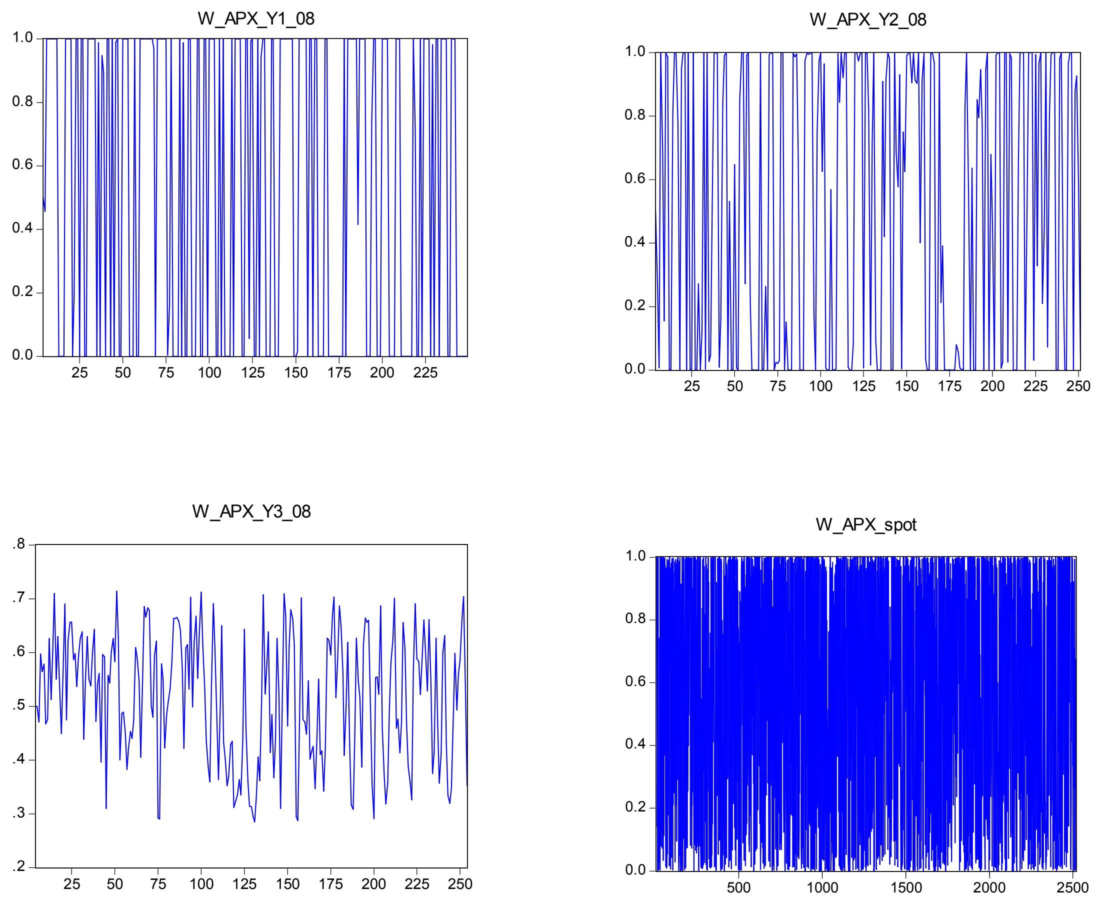
Table 4: Descriptive statistics weights

	APX				EEX				Nordpool			
	Y1	**Y2**	**Y3**	**Spot**	**Y1**	**Y2**	**Y3**	**Spot**	**Y1**	**Y2**	**Y3**	**Spot**
Mean	0.5526	0.5164	0.5179	0.5666	0.5043	0.5248	0.4847	0.5476	0.5147	0.4294	0.6313	0.5559
Median	0.9999	0.6253	0.5286	0.6502	0.7870	1.0000	0.4089	0.6890	0.9306	0.0000	1.0000	0.7304
Maximum	1.0000	1.0000	0.7143	0.9997	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Minimum	0.0000	0.0000	0.2853	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Std. Dev.	0.4908	0.4501	0.1165	0.3913	0.4980	0.4974	0.4779	0.4403	0.4951	0.4915	0.4810	0.4419
Skewness	-0.2137	-0.0899	-0.2366	-0.2128	-0.0194	-0.0986	0.0553	-0.1581	-0.0624	0.2856	-0.5454	-0.1974
Kurtosis	1.0677	1.1627	1.9868	1.3520	1.0087	1.0181	1.0722	1.1787	1.0211	1.0960	1.3090	1.1956
Jarque-Bera	40.1427	35.2178	13.0772	303.7077	40.6580	40.8248	38.8404	358.2333	40.1337	40.8325	32.9032	306.2131
Probability	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	135.9513	128.0773	129.9860	1425.5980	124.0662	129.6240	121.1635	1377.6600	126.1055	106.4966	123.1104	1197.4100
Sum Sq. Dev.	59.0235	50.0384	3.3946	385.0244	60.7613	60.8633	56.8665	487.4985	59.8143	59.6599	44.8907	420.3909
Observations	246	248	251	2516	246	247	250	2516	245	248	195	2154

Notes: Table 4 presents the descriptive statistics of the estimated weights, or the fraction of chartists in the market.

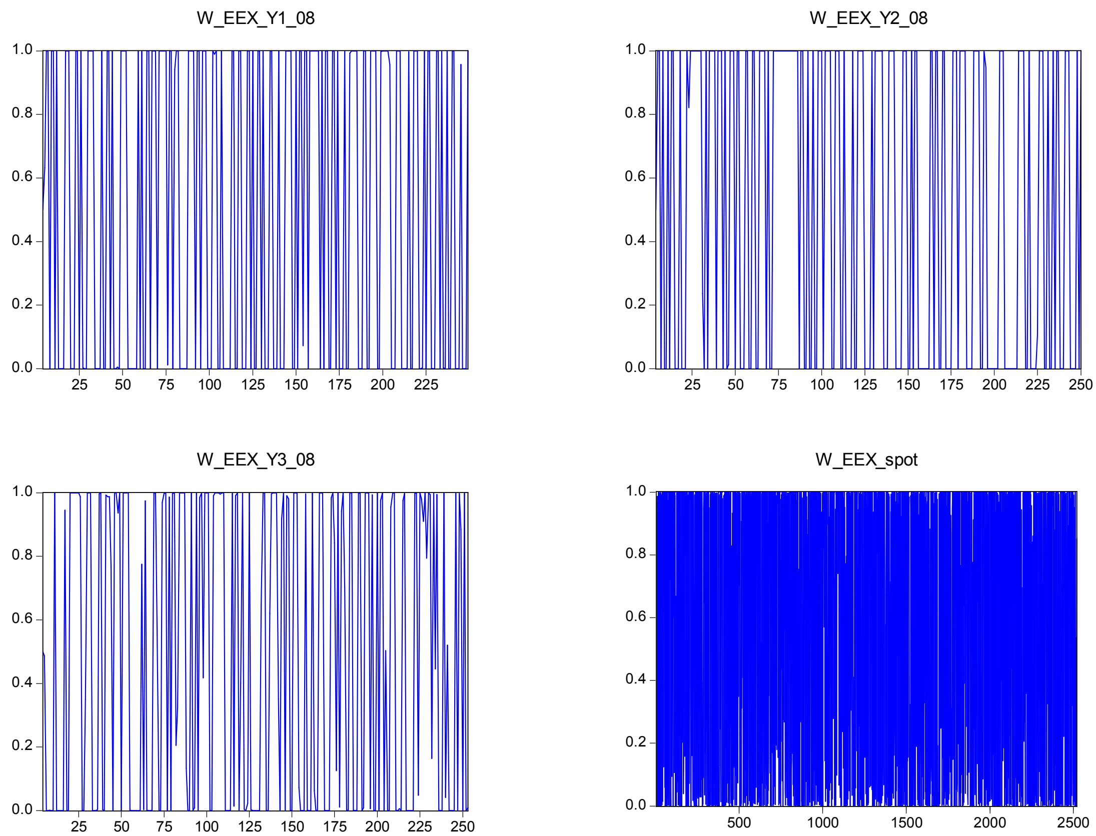
APPENDIX D Graphs weights

Figure 2a: Weights APX exchange



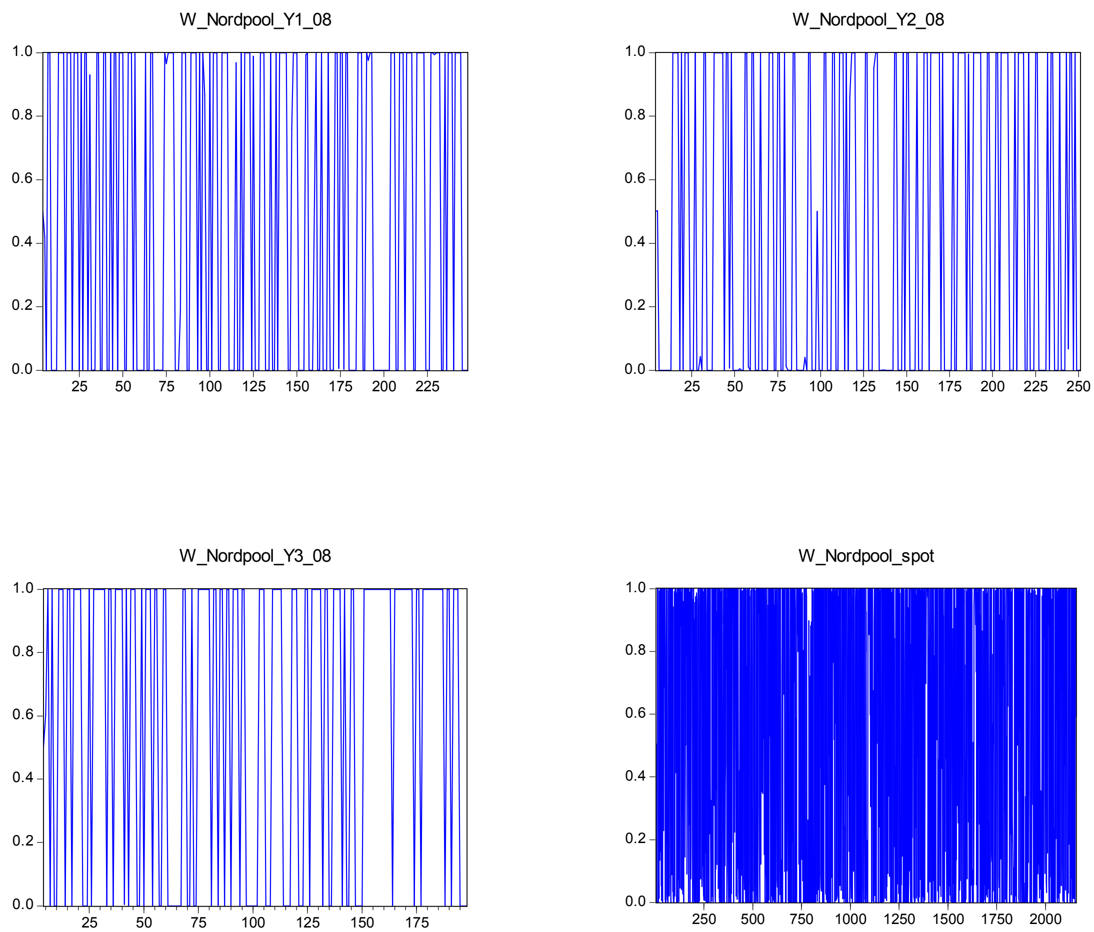
Notes: Figure 2a displays the time series of weight of the APX market for the 1-, 2-, 3-year future contracts and the spot market. The weight represents the fraction of chartists in the market.

Figure 2b Weights EEX exchange



Notes: Figure 2a displays the time series of weight of the EEX market for the 1-, 2-, 3-year future contracts and the spot market. The weight represents the fraction of chartists in the market.

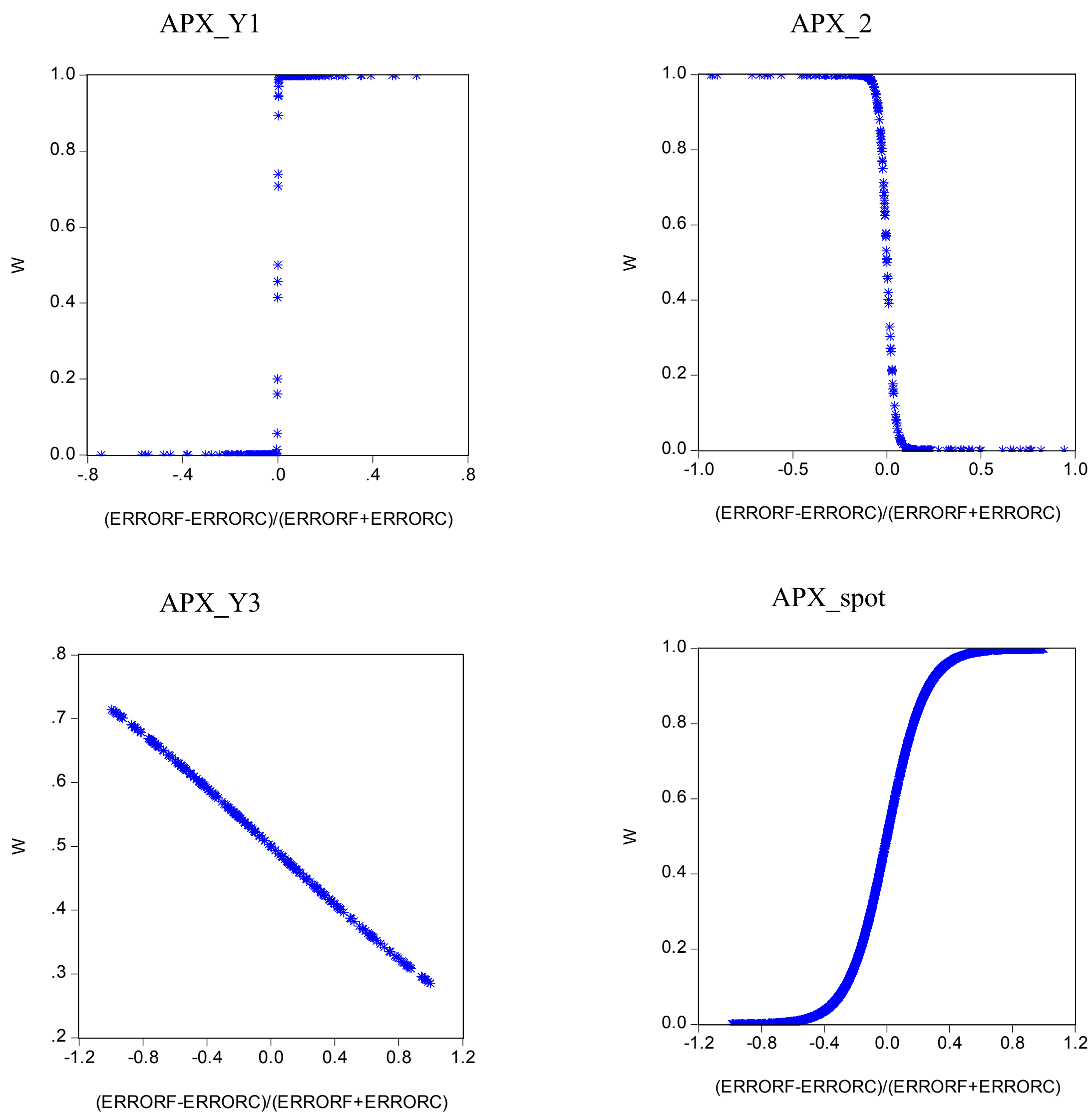
Figure 2c: Weights Nordpool exchange



Notes: Figure 2a displays the time series of weight of the Nordpool market for the 1-, 2-, 3-year future contracts and the spot market. The weight represents the fraction of chartists in the market.

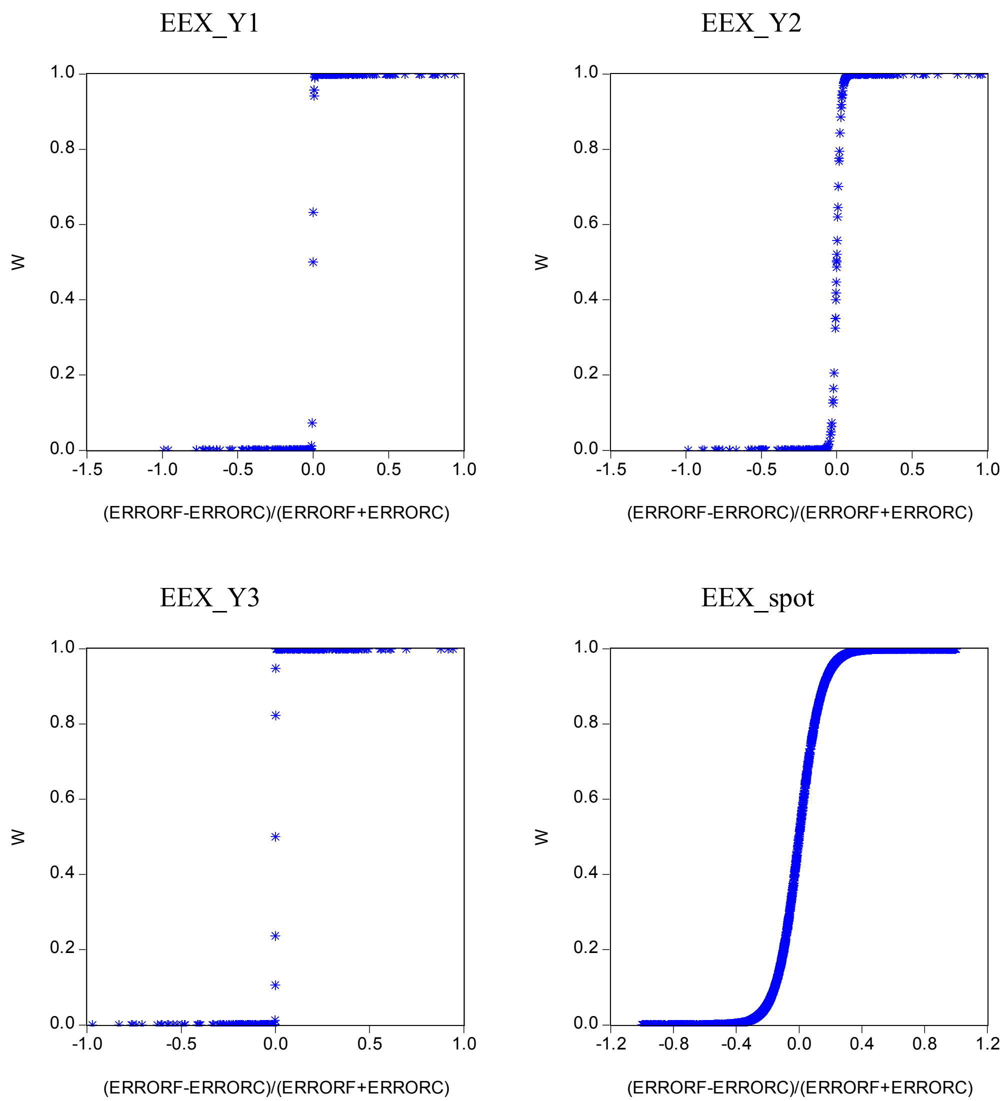
APPENDIX E S-shaped graphs

Figure 3a: Graphs showing relationship between the forecasting errors, weights and the intensity of choice for the APX exchange.



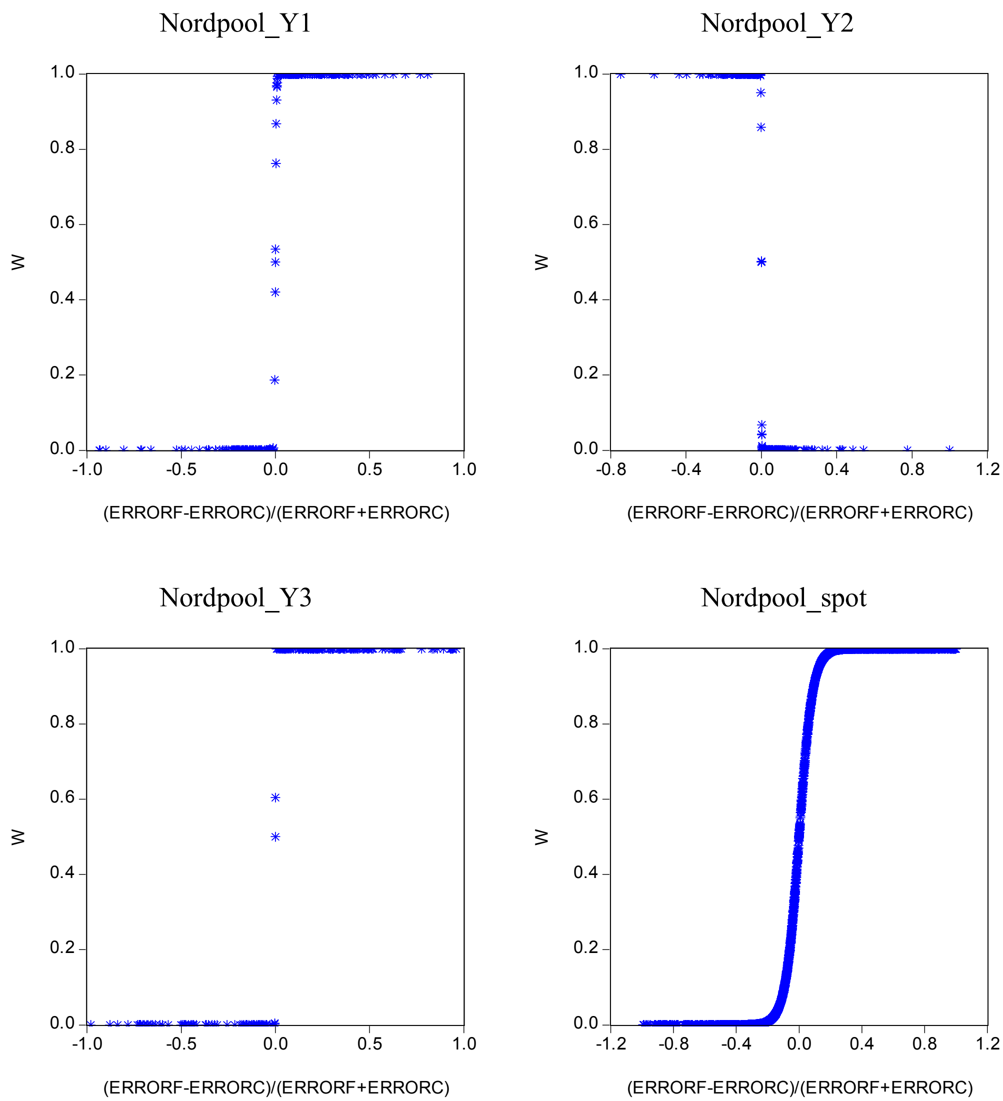
Notes: Figure 3a displays graphs which present the chartist weight (y-axis) versus the relative difference in the performance of the strategies (x-axis) for the APX exchange.

Figure 3b: Graphs showing relationship between the forecasting errors, weights and the intensity of choice for the EEX exchange.



Notes: Figure 3b displays graphs which present the chartist weight (y-axis) versus the relative difference in the performance of the strategies (x-axis) for the EEX exchange.

Figure 3c: Graphs showing relationship between the forecasting errors, weights and the intensity of choice for the Nordpool exchange.



Notes: Figure 3c displays graphs which present the chartist weight (y-axis) versus the relative difference in the performance of the strategies (x-axis) for the Nordpool exchange.

APPENDIX F Correlation table weights

Table 5: Correlation table weights

		APX				EEX				Nordpool			
		Spot	**Y1**	**Y2**	**Y3**	**Spot**	**Y1**	**Y2**	**Y3**	**Spot**	**Y1**	**Y2**	**Y3**
APX	**Spot**	1											
	Y1	0.108397	1										
	Y2	0.076872	-0.06354	1									
	Y3	-0.095387	0.074558	-0.055771	1								
EEX	**Spot**	0.547971	0.026565	0.11323	-0.073266	1							
	Y1	0.03236	0.357478	-0.132553	0.037286	0.005809	1						
	Y2	-0.012308	0.037839	-0.283017	-0.015754	-0.042084	0.013829	1					
	Y3	-0.077175	0.050056	-0.112046	0.328367	0.048768	0.017775	0.061881	1				
Nordpool	**Spot**	0.013654	-0.049348	-0.104422	0.008458	-0.038145	-0.00419	0.134564	0.078405	1			
	Y1	-0.067703	-0.110373	0.025494	-0.047741	0.023776	-0.111235	0.022681	-0.022264	0.070861	1		
	Y2	-0.072951	-0.016184	0.142668	-0.151655	0.014032	-0.060786	-0.08009	-0.029009	0.085303	-0.01362	1	
	Y3	-0.030094	-0.137454	-0.04109	-0.159205	-0.014622	0.009163	0.02144	-0.048265	0.15734	-0.047676	-0.023775	1

Notes: Table 5 presents the correlation between the weights of the different contracts and markets.