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The Exchange Rate and a Heterogeneous Agent Model.

A study about the effect of Fundamentalists and Chartists on the USD/Euro Exchange Rate

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PREFACE AND ACKNOWLEDGEMENTS

This thesis is written to close a very special time at the Erasmus University in Rotterdam. I had a great time and learned a lot from the people I met. I want to thank Jan Lemmen for his advice, help and patience with both of my theses. I also want to thank my friends and family for always supporting me. Especially my parents and my little sister, your unconditional love and support are very special to me. Also a special thanks to my love for your guidance, your support and always believing in me.

ABSTRACT

This study examines whether a heterogeneous agents model (HAM) can explain the fluctuations of the USD/Euro exchange rate in the short run. Assumed in this study is that agents can choose either the fundamentalist strategy or the chartist approach. The results of this study show that fundamentalists are only significantly active when agents do not switch between strategies and when the currency is undervalued. Chartists are only active after a negative trend in the USD/Euro exchange rate.

Keywords: Exchange rates, Disconnect puzzle, Behavioural finance, Fundamentalists, Chartists
JEL classification: D03, E03, F31, G02

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 Introduction

The US-dollar was introduced in 1792 and since the end of World War Two it is the most important currency in international trading. For example gold and oil prices are expressed in US-dollars. However, since the introduction of the Euro in 2002, the US-dollar is fluctuating a lot.

Exchange rates are studied many times in the past years. It seems that in the long-run, exchange rates are linked with macroeconomic fundamentals. However, in the short-run this is not the case. Exchange rates show many disconnections with their fundamentals in the short-run. The behavioural finance calls this the '*exchange rate disconnect puzzle'*. A possible explanation for this puzzle is that market forecasts are irrational. The literature mentions that investors' expectations are biased. Most studies about noise traders, investor sentiment and heterogeneous agents conclude that investors are consistently irrational. Heterogeneous means that there are no similar agents in the market. Every agent follows a different trading strategy.

There are already many articles about the stock market and heterogeneous agent models. For example, Boswijk et al. (2007) and Amilon (2008) studied the effect heterogeneous agents on stock prices. This study will examine the effect of heterogeneous agents on the USD/Euro exchange rate over the past 25 years. The literature already mentions that there might be a relation between speculation and exchange rates. The research question of this study is: What is the effect of heterogeneous agents on the USD/Euro exchange rate?

A well-known problem in the international macroeconomics and finance is that exchange rates are very volatile and are strongly disconnected from there fundamentals (Obstfeld & Rogoff, 2001). Flood and Rose (1997) emphasize this disconnection with the quote that exchange rates seem to have 'a live of its own' (Flood & Rose, 1995). In a logical economic way you would expect that variables like national income, money growth and inflation would be the fundamentals that could determine the exchange rate. These assumptions are also made in one of the first models that tried to determine the exchange rate: the monetary model (Hopper, 1997). In the economy it is very alarming that these fundamentals are not able to predict the exchanges rates. If there was a way to predict the exchange rate, many businesses and other investors would be able to make better informed and efficient decisions. The primary reason of this study is trying to understand what determines the exchange rate. If an answer to this

question can be found, this would be a breakthrough in the international macroeconomics and finance.

The remainder of this thesis is structured as follows: Section 2 contains a literature review, in which the exchange rate market and behavioural finance theory are discussed. Section 3 explains the dataset used in this study. The methodology is discussed in Section 4 and the results of this study are shown in Section 5. Section 6 contains the conclusion and some suggestions for further research.

CHAPTER 2 Existing literature and theoretical models

This chapter contains a literature review, in which the exchange rate market and behavioural finance theory are explained. Results from studies which examined the exchange rate market are discussed, as well as results from studies which use behavioural finance theory.

2.1 Disconnect puzzle

In economic literature the exchange rate market has been examined a lot of times. Most researchers try to find an explanation for the disconnection between the underlying fundamentals and the exchange rates. Researchers find evidence for puzzles in the exchange rate market. One of these puzzles is the exchange rate disconnect puzzle.

The exchange rate disconnect puzzle refers to the fact that there is a missing link between the exchange rate and the macroeconomic fundamentals. Sometimes exchange rates become extremely volatile, whereas the fluctuations in the macroeconomic fundamentals remain unchanged. The fundamentals in the monetary models are for example money supply, interest rates and the output of a country. The international macroeconomic theory suggests that these variables are important in explaining the movement and volatility of the exchange rate. However, the exchange rate disconnect puzzle shows that the exchange rate and the macroeconomic fundamentals are not moving in the same direction. Also the volatility of the exchange rate is far more extreme than the underlying fundamentals (Jindrova, 2007). There seems to be no monetary model yet that can explain exchange rates better than a random walk model. The random walk model assumes that the exchange rate at time *t* depends on the exchange rate at *t-1* plus some noise.

2.1.1 No disconnection in the long-run

On the other hand, many empirical researchers already found a relation between exchange rates and the macroeconomic fundamentals in the long-run. Sarno and Taylor (2003) found evidence that there is a link between the exchange rate and the macroeconomic fundamentals at longer horizons. They also state that empirical models of exchange rate determination can be used to forecast exchange rates. However, the results of their study indicate a strong disconnection between the exchange rate and the macroeconomic fundamentals at shorter horizons. The authors state that, in the short-run, it is still difficult to beat the random walk model (Sarno & Taylor, 2003). In their paper, Meese and Rogoff (1983) refer to this phenomenon as the exchange rate disconnect puzzle. They state that there is a very weak relation between the

exchange rate and any macroeconomic fundamental (Meese & Rogoff, 1983). Mark (1995) also found evidence that on shorter horizons changes in the exchange rate are mostly due to noise, while at longer horizons this noise seems to disappear. Exchange rate movements are then determined by economic fundamentals (Mark, 1995). Similarly, Wang (2008) discusses that, in the long-run, changes in the exchange rate can be explained by the fundamentals. Most models that try to determine the exchange rate in the short-run do not outperforme random walk models. However, in the long-run, the fundamentals seem to outperforme random walk models (Wang, 2008). So there is evidence that in the long-run the economic models do work and are able to predict the exchange rate. The disconnection is thus especially noticeable in the short-run.

2.2 Many studies, no clear explaination

Looking at the literature, one could say that there already has been many research in explaining the exchange rate without any succes. It is still unclear why in the short-run the exchange rate shows such a huge disconnection with the macroeconomic fundamentals and why the volatility of the exchange rate is so high.

It may be the case that researchers studied the exchange rate with the wrong assumptions. Neoclassical models like the Rational Expectation Hypothesis model make assumptions that do not describe real human behaviour. In these standard economic models or traditional economic theory like the neoclassical economic model of rational behaviour, feelings and emotions are dismissed. These models make the assumption that investors have access to all available information and that they have the knowledge and skills to use this information in such a way that they make rational choices. The only distortions that can occur are due to noise. However, the efficient market hypothesis states that markets are efficient and noise will be cleared out by rational traders. If this distortion stays, it will only have effect in the short-run behaviour of investors and not in the long-run (Bormann, 2013). When applying these standard economic models, empirical evidence shows that these models are not able to explain the exchange rate formation (Dick & Menkhoff, 2013). According to Frankel and Froot (1990), the gap between the macroeconomic fundamentals and the exchange rate can be explained by the high degree of heterogeneity between market participants (Frankel & Froot, Chartists, Fundamentalists, and Trading in the Foreign Exchange Market, 1990). In other words, agents in the market differ in their trading strategy. Some agents will look at historical prices, others will look at fundamentals and there are also agents who base their trading strategy on noise.

2.3 Rational Expectation Hypothesis

Since Muth introduced the Rational Expectation Hypothesis in the sixties, the model is the most dominating expectations model in economic theory. The model assumes that all agents are rational and have perfect knowledge about the market equilibrium equations. They use this knowledge to form their expectations. The word rationality used in this model means two things: First, when the assumption is made that agents are rational and they receive new information, agents are supposed to update their beliefs correctly. The second meaning is that agents make choices that are consistent with the Subjective Expected Utility (Barberis & Thaler, 2003). In Finance, the model that is related to the Rational Expectation Hypothesis is the Efficient Market Hypothesis (EMH). According to EMH, prices are right when the actual price equals the fundamental value. The main argument why economists must assume that markets are efficient is the arbitrage argument (Hommes, 2005). If a market is not efficient, a rational trader could make lots of profits. They would buy assets which are underpriced or sell assets which are overpriced. This will cause the asset price to move back towards its fundamental value (Hommes, 2005).

2.4 Behavioural Finance

Evidence shows that we have to look beyond these standard economic models and look in other areas that combine human behaviour and economics. Behavioural finance is such a theory that focuses on the behaviour of market participants. In their paper, Barberis and Thaler (2003) state: '*Behavioural finance argues that some financial phenomena can be better understood using models in which some agents are not fully rational* ' (Barberis & Thaler, 2003). Behavioural finance is based on two starting points. The first one is limits to arbitrage. This means that it is a difficult and risky task for rational traders to correct the mispricing caused by irrational traders. The riskiness occurs when in the short-run a lot of irrational traders follow a trend; the mispricing can get worse in these cases. The second starting point in behavioural finance is market psychology. With this concept, researchers are trying to explain which heuristics and biases play a role in financial markets (Hommes, 2006).

So, the behavioural finance researchers mainly look at the behaviour of individual investors rather than looking at fundamenals. They assume that future expectations of heterogeneous agents could have an effect on the exchange rate. Like Keynes already mentioned decades ago, 'expectations matter'. By this statement he meant that when you examine the financial market, it is important to take investor sentiment and market psychology into consideration. Keynes also argued that for individual investors it is very difficult to determine what the correct

fundamentals are. He also stated that it is a difficult task to compute an objective measurement of market fundamentals (Keynes, 1936).

2.4.1 Boundedly rational

In the past decades many researchers criticized this standard neoclassical model. This is because the agents described in the models have many limitations and the assumptions that are made in the models are not very realistic. For market participants it is costly to gather information and even if they are able to gather the information they do not always have the knowledge, skills or time to process all available information. Simon (1955) argued that because of these limitations it is far more reasonable to assume that investors make decisions based on simple rules of thumb. He calls these investors bounded rational agents. A boundedly rational agent forms his beliefs based on observable quantities and only changes his forecast when complementary observations become available (Simon, 1955). Assuming that investors are bounded rational agents is a much more realistic view to real human behaviour than models that assume that people are perfectly rational and make decisions based on optimal decision rules.

2.5 Investor sentiment

Another building block of behavioural finance is investor sentiment. Investor sentiment implies that investors' preferences are formed by beliefs and expectations. In understanding investors' trading strategies, it is important to understand their preferences. These preferences show how investors deal with risk and uncertainty. A theory that can explain investors preferences best is the Prospect Theory developed by Kahneman and Tversky in 1979. Their study shows that investors are risk seeking over losses but they are risk averse over gains. Furthermore, the results of their study show that investors have loss aversion, meaning that they have a greater sensitivity towards losses (Kahneman & Tversky, 1979). Prospect Theory gives a clear look to the irrationality of investors behaviour in the market. Because investors are loss averse, they are willing to undergo greater risk to avoid the possibility of a loss. Many evidence is found that investors are often unwilling to sell an asset, such as a stock, which decreases in value. Investors have the hope that the stock will perform better in the future, while often the price of the stock is declining more and more.

Like said before, investors are boundedly rational. They do not always have the ability or skills to process new information rationally. Many biases are made in decision making, because investors often rely on frames and heuristics.

2.6 Heterogeneous Agent Models

First the rational agent model and the efficient market hypotheses were very popular models but in the late eighties and nighties, due to much more criticism, heterogeneous agent models and bounded rationality models gained in popularity (Hommes, 2006). Economics and Finance underwent major fundamental changes in their underlying assumptions. There has been a changed idea of the composition of the market (Hommes, 2006). Where the assumption first was that markets largely consist of rational agents, nowadays there are also assumptions that markets consist of boundedly rational agents. Whereas standard economical models, which assume that there are only perfect rational agents, become less popular, there is more space for new models which include behaviour of market participants.

2.6.1 Noise traders and sophisticated traders

One of the heterogeneous agent models was introduced by Delong et al. (1990). They presented a model with two types of traders: noise traders and sophisticated traders. Noise traders think they have special information about the future price of a risky asset. Those believes are caused by signals noise traders get. They believe that these signals contain information, which actually is just noise. The problem is that noise traders compose their portfolios on such false beliefs. Sophisticated traders' strategy is a reaction on what noise traders do. When noise traders sell their assets, sophisticated traders know that this is wrong and they will buy the assets to move the asset more towards its fundamental value. The same strategy is maintained when noise traders buy more of an asset. In this case, sophisticated traders try to correct the misperception of noise traders in an attempt to move the price of the asset more towards the fundamental value. Because of noise traders, there can be a great gap between the price of assets and its fundamental value. Sophisticated strategies push the price more towards the fundamental value, but not completely (De Long, Shleifer, Summers, & Waldmann, 1990).

2.6.2 Fundamentalists and Chartists

The most well-known heterogeneous models is the one that distinguishes the following two types of agents: the fundamentalist and the chartist. The name already gives away were a fundamentalist stands for. They form their expectations about the future and their strategies upon market fundamentals. In forming expectations about the future value of the exchange rate, fundamentalists take into account macroeconomic fundamentals, such as inflation or GDP-growth (Hommes, 2006). The trading strategy of fundamentalists depends on the degree of over- or undervaluation of the exchange rate. In the case of overvaluation, the spot price is

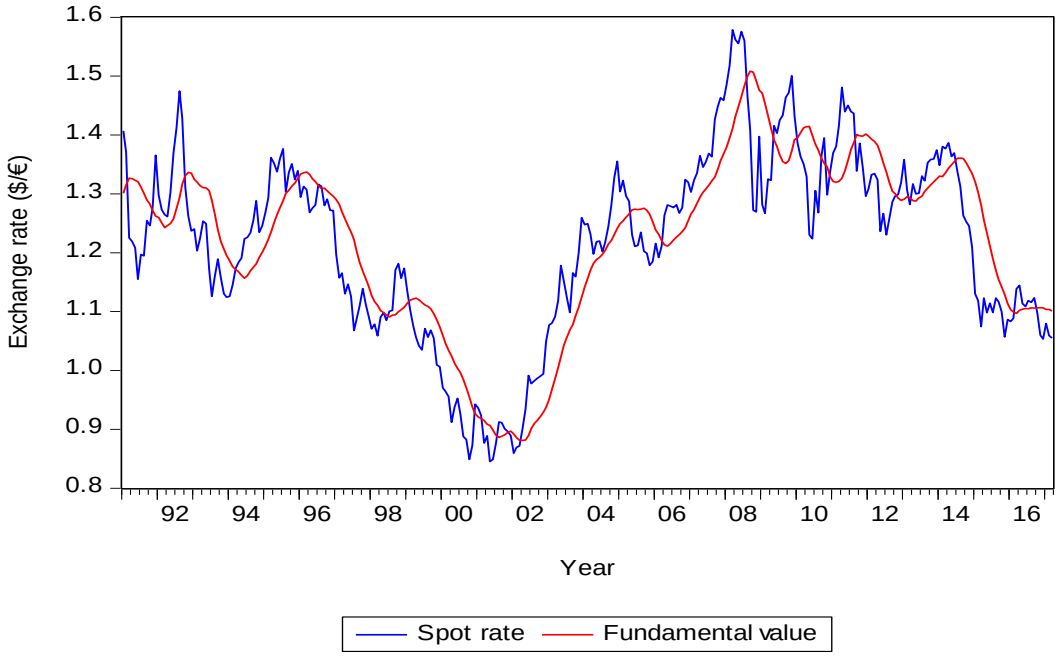
above the fundamental value. Fundamentalists than follow a strategy in which they sell the currency they own. When a large group of fundamentalists will sell the currency which they believe is overvalued, the price of the currency will decrease and will come closer towards its fundamental value. In the case of undervaluation, the spot price is below the fundamental value. To drive the price up towards its fundamental value, fundamentalists will increase the demand of the currency. When a large group of fundamentalists will buy the currency of which they believe it is undervalued, the price of that currency will increase and will come closer towards the fundamental value. This indicates that fundamentalists act mean-reverting. Fundamentalists are aware of the presence of chartists. They believe that the exchange rate would equal to the fundamental price if there were no chartists in the market. They also believe that with their trading strategy the exchange rate eventually reaches its fundamental value in the long-run. The second agent in this heterogeneous agent model is the chartist. A chartist forms his expectations about the future upon observations of historical patterns (Hommes, 2006). A chartist does not take into account that fundamentalists are also present in the market. A chartist forms his expectations about the future and his strategies upon historical data. Chartists are looking for patterns in the historical data, such as trends. A trend occurs when the price rises or falls a few successive periods. When such a pattern is found, chartists extrapolate this pattern or trend into the future (Hommes, 2006). Therefore, the trading strategy of chartists is called trending. In heterogeneous agent models, which consist of fundamentalists and chartists, fundamentalists have a stabilizing effect on the exchange rate and chartists have a destabilizing effect on the exchange rate. This study will test if this is the case for the USD/Euro exchange rate.

CHAPTER 3 Data

The data used in this study is derived from Bloomberg. To study the effect of heterogeneous agents on the exchange rate, the USD/Euro exchange rate is chosen. This exchange rate is chosen, because the US-dollar is one of the most widely used currencies in the world. Oil and gold prices are expressed in US-dollars, but also perishable commodities like coffee and metal are expressed in US-dollars. The US-dollar still is the most popular currency in world trade. However, since its introduction, the Euro became the second most traded currency in the world (Investopedia, 2017). The data covers a period from the 1st of January 1991 till the 1st of March 2017. Since the Euro did not exist until 2002, the German Mark is used from 1991 till 2002, because at that time it was the strongest currency in Europe.

In order to test the effect of fundamentalists on the USD/Euro exchange rate, the fundamental value of the exchange rate has to be estimated. In his study, Frenkel (1997) states that for simplicity, the moving average of the spot rate can be used to estimate the fundamental value of the exchange rate (Frenkel, 1997). In a study about the oil market, Ter Ellen and Zwinkels (2010) use a two-year moving average to estimate the fundamental value of oil. According to Singer (2017), exchange rates reach their fundamental value faster than bonds and equity. Therefore, in this study the fundamental value of the exchange rate is calculated by the one-year moving average of the spot rate. The graphs in Figure 1 below show the movements of the USD/Euro exchange rate and its fundamental value over the sample period.

Figure 1: Graph of the USD/Euro exchange rate between 1991 and 2017



To clarify the movements of the exchange rate and its fundamental value, some descriptive statistics of the two variables are needed. These can be found in Table 1 below. The mean and median values of the Euro/USD exchange rate are both higher than one. That means that the Euro is, on average, stronger than the US dollar. In other words, every Euro costs $ 1.22 on average. However, three years long, the US dollar was stronger than the Euro. In the years 2000, 2001 and 2002 the Euro/USD exchange rate was lower than one. In 2001 the dollar reached its highest value in the past 15 years. At that time, a Euro only cost $ 0.85. In 2002, the Euro was introduced as a new currency for the Eurozone. After this period, the Euro became stronger. The US dollar decreased in value and eventually in 2008, it reached its lowest value in the past decades. During the financial crisis in that period, one had to pay $ 1.58 per Euro. In other words, the US dollar was only worth € 0.63. Table 1 shows that on average, the fundamental value of the exchange rate is higher than the spot rate over the sample period. Table 1 also shows that the Kurtosis is below three. Skewness is negative, which means that the distributions of the USD/Euro exchange rate and its fundamental value are skewed to the left. The Jarque-Bera test is also performed for both the spot and fundamental exchange rate. For both variables the null hypothesis for a normal distribution can be rejected at a 5% significance level. In other words, the data in this study is not normally distributed.

Table 1: Descriptive statistics of the USD/Euro exchange rate and its fundamental value

	Spot rate	Fundamental value
Mean	*1.2170*	*1.2222*
Median	*1.2404*	*1.2600*
Maximum	*1.5788*	*1.5084*
Minimum	*0.8453*	*0.8809*
Std. Dev.	*0.1570*	*0.1471*
Skewness	*-0.3622*	*-0.6663*
Kurtosis	*2.7367*	*2.7928*
Jarque-Bera	*7.7972*	*23.8695*
Probability	*0.0203*	*0.0000*
Observations	*315*	*315*

CHAPTER 4 Methodology

To determine whether fundamentalists and chartists have an effect on the exchange rate, a heterogeneous agent model (HAM) will be used. This section explains the model and its assumptions. The model used in this study is based on the model Frankel and Froot (1990) and (1991) use in their paper.

4.1 Fundamentalists

Like described in section 2.5.1, fundamentalists are agents who base their expectation on market fundamentals. The expected change of the exchange rate according to fundamentalists is given by the following equation:

$$\Delta S_{t+1}^{f} = v(\bar{S} - S_t) \qquad (1)$$

where ΔS_{t+1}^{f} is the fundamentalists' expected change of the exchange rate in the next period. S_t is the spot rate at time *t* and the fundamental exchange rate is given by $\bar{S}$. The speed of adjustment is given by v. This coefficient shows how strong fundamentalists react to a difference between the fundamental exchange rate and the spot rate. When the fundamental exchange rate is higher than the spot rate, fundamentalists will expect the exchange rate to increase in the next period. If the fundamental exchange rate is lower than the spot rate, fundamentalists will expect the exchange rate to decrease in the next period. This shows that fundamentalists try to move the exchange rate towards its fundamental value. However, according to the study of Kahneman and Tversky (1979) agents behave different when it comes to losses and gains. Kahneman and Tversky (1979) call this Prospect Theory, which states that agents are risk averse for positive prospects and risk seeking for negative ones (Kahneman & Tversky, 1979). This theory suggests that fundamentalists could react stronger when a currency is undervalued than when it is overvalued. To test this, v in equation 1 can be split into two separate coefficients:

$$\Delta S_{t+1}^{f} = v_1(\bar{S} - S_t)^o + v_2(\bar{S} - S_t)^u \qquad (1.1)$$

where $(\bar{S} - S_t)^o$ stands for a situation where the exchange rate is overvalued. In other words, there is an overvaluation when the spot rate is higher than the fundamental exchange rate. v_1 shows how strong fundamentalists react to an overvalued exchange rate. When the spot rate is higher than the fundamental exchange rate, $(\bar{S} - S_t)^o$ has a negative value. Because

fundamentalists want the spot rate to move towards its fundamental value, v_1 is expected to be positive. Fundamentalists will expect the spot rate to decrease in the next period. An undervalued exchange rate is given by $(\bar{S} - S_t)^u$. An exchange rate is undervalued when the spot rate is lower than its fundamental value. v_2 is expected to be positive, because in times of undervaluation, fundamentalists expect the spot rate to increase the next period so that it can move towards its fundamental value. Another expectation is that v_2 will have a higher absolute value than v_1, because Prospect Theory suggests that agents react stronger to a negative prospect.

4.2 Chartists

Chartists form their expectations and strategies about the future upon historical data. Just like the fundamentalists, chartists could also react different to positive and negative prospects. The expected change of the exchange rate according to chartists is given by the following equation:

$$\Delta S^c_{t+1} = \theta_1(S_t - S_{t-1})^p + \theta_2(S_t - S_{t-1})^n \qquad (2)$$

where ΔS^c_{t+1} is the chartists' expected change of the exchange rate in the next period. S_t is the spot rate at time *t* and S_{t-1} is the spot rate at time *t-1*. The equation shows that chartists base their future expectations on patterns in historical data, such as trends. For simplicity, this model uses a chartist who bases his expectations only on the previous period. $(S_t - S_{t-1})^p$ stands for a positive 'trend'. This is the case when the spot rate increased in the previous period. $(S_t - S_{t-1})^n$ stands for a negative 'trend', so when the spot rate decreased in the previous period. θ_1 and θ_2 show how strong chartists react to changes in the exchange rate in the previous period. If the exchange rate shows a positive trend, which means an increase of the spot rate in the previous period, chartists will expect the exchange rate to increase in the next period. Therefore θ_1 is expected to have a positive value. θ_2 is expected to have a positive value too, because a after a decrease in the previous period, chartists will expect the exchange rate to decrease further in the next period. Just like the fundamental strategy, θ_2 is expected to have a higher absolute value than θ_1, because of Prospect Theory.

4.3 Choosing a strategy

This study assumes that agents in the market can only choose between the fundamentalist or chartist strategy. Many studies have shown that once an agent chooses a strategy, it does not mean that they cannot switch between strategies. Agents want to evaluate the strategy they use, in order to choose the best strategy for future investments (Hommes, 2006). Therefore, the performance of a strategy has to be determined.

In their paper, Ter Ellen and Zwinkels (2010) state that the performance of a strategy is measured by the forecasting error of the strategy. The following equation shows how the forecasting performance of the fundamentalist strategy is calculated:

$$A_t^f = -\sum_{k=1}^{K} \left[\Delta S_{t-k}^f - \Delta S_{t-k}\right]^2 \qquad (3)$$

where A_t^f is the performance of the fundamentalist strategy and ΔS_{t-k} is the actual change of the spot rate at time $t-k$. The forecasting performance of the chartist strategy is calculated as follows:

$$A_t^c = -\sum_{k=1}^{K} \left[\Delta S_{t-k}^c - \Delta S_{t-k}\right]^2 \qquad (4)$$

where A_t^c is the performance of the chartist strategy. *K* is the number of periods the agents look back in order to decide which strategy performs best. The optimal *k* is chosen by looking at the lowest AIC (Akaike Information Criterion). The optimal *k* in this study is 2. Ter Ellen and Zwinkels (2010) state that agents switch between the two strategies, based on the relative performance of the strategies. Switching between the two strategies is given by the following equation:

$$\omega_t = \left[1 + exp\left(-\gamma \left[\frac{A_t^f - A_t^c}{A_t^f + A_t^c}\right]\right)\right]^{-1} \qquad (5)$$

In this equation ω_t shows what fraction of the agents follow the fundamentalist strategy. ω_t has a value between 0 and 1, where $\omega_t = 1$ means that there are only fundamentalists active in the market and $\omega_t = 0$ means that all agents are chartists. γ stands for the intensity of choice. If $\gamma = \infty$, agents are perfectly adaptive. They will choose the strategy which performs best. If the fundamentalist strategy performs better than the chartist strategy, so when $A_t^f > A_t^c$, ω_t will have a value of 1 and vice versa (Ter Ellen & Zwinkels, 2010). When $\gamma = 0$, agents do not adapt their strategy based on the performance of the strategies. In this case, ω_t has a value of 0,5, which means that one half of the agents follow the fundamentalist approach, while the other half is chartist.

4.4 Final model

In a market with only fundamentalists and chartists, the change of the exchange rate is determined by the following equation:

$$\Delta S_{t+1} = \omega_t \Delta S^f_{t+1} + (1 - \omega_t)\Delta S^c_{t+1} \qquad (6)$$

where (ΔS_{t+1}) is the change of the exchange rate at time *t+1* and $(1 - \omega_t)$ is the fraction of agents who follow the chartist strategy. By substituting equations 1.1 and 2 into 6, the final model that will be tested is as follows:

$$\Delta S_{t+1} = \omega_t(v_1(\bar{S} - S_t)^o + v_2(\bar{S} - S_t)^u) + (1 - \omega_t)(\theta_1(S_t - S_{t-1})^p + \theta_2(S_t - S_{t-1})^n) \qquad (7)$$

Equation 7 shows that the change of the spot rate at time *t+1* depends on two types of agents: the first one is fundamentalist and his reaction to an overvalued or undervalued exchange rate. The second agent is a chartist who follows a positive or negative trend.

CHAPTER 5 Results

In this section the results will be shown and discussed.

5.1 Test without switching between strategies

To test whether fundamentalists and chartists are active in the exchange rate market and if they have an effect on the USD/Euro exchange rate, equation 7 is tested. The first test is done with the assumption that the intensity of choice parameter, γ, is equal to 0. This means that ω_t has a value of $\frac{1}{2}$. The fraction of agents who follow the fundamental strategy is equal to the fraction of agents who follow the chartist strategy. Agents do not look at the performance of the two strategies and they will not switch between the fundamentalist and chartist strategy. The results of this test are shown below in Table 2.

Table 2: Results of the full model without switching between strategies

	v_1	v_2	θ_1	θ_2
Coefficient	*-0.0862*	*0.1554*	*-0.1946*	*0.4561*
P-value	*0.4108*	*0.0954**	*0.3709*	*0.0254***

Note: this table shows the results of the full model (equation 7). The values of the coefficients and their P-values are shown. * and ** are placed above the P-value when the coefficient is significant at a significance level of 10% or 5%, respectively.

The results show that there are indeed fundamentalists and chartists active in the exchange rate market. Looking at the fundamentalist strategy, v_1, which stands for the reaction of fundamentalists to an overvalued currency, does not have the expected sign. The expectation was that v_1 would have a positive value, because if the spot rate is higher than the fundamental exchange rate at time *t*, fundamentalists would expect the exchange rate to decrease in the next period. The coefficient is positive, however it is not significant at either a 5% or 10% significance level. v_2, which stands for a fundamentalist's reaction to an undervalued currency, does have the expected sign. The expectation was that a fundamentalist would expect the spot rate to increase in the next period, if the currency was undervalued at time *t*. As expected, according to Prospect Theory, the coefficient of v_2 is higher than v_1, which means that fundamentalists react stronger when a currency is undervalued. The coefficient of v_2 is significant at a significance level of 10%, which means that in times of undervaluation, fundamentalists are active in the exchange rate market.

Looking at the coefficients of the chartist strategy, the results are almost the same as the fundamentalist strategy. θ_1, which stands for a chartist's reaction to a positive trend, does not

show the expected sign. The expectation was that chartists would expect the spot rate to increase after a positive trend. However, θ_1 is not significant. As expected, the coefficient of θ_2 has a higher value than θ_1, which means that chartists react stronger to a negative trend. At a 5% significance level, θ_2 is significant, which means that there are chartists active in the exchange rate market after a period of decreasing spot rates.

In other words, the results imply that the change of the spot rate at time *t+1* is affected by fundamentalists when the exchange rate is undervalued at time *t*. Chartists also have an effect on the change of the spot rate at time *t+1,* but only after a period of decreasing spot rates.

5.2 Test with switching between strategies

Equation 7 is tested again, but now with the assumption that agents do switch between the two strategies, based on the performance of the strategies. The results of the test are shown below in Table 3.

Table 3: Results of the full model with switching between strategies

	γ	v_1	v_2	θ_1	θ_2
Coefficient	*0.3496*	*-0.1078*	*0.1422*	*-0.1963*	*0.4410*
P-value	*0.7504*	*0.3196*	*0.1424*	*0.3566*	*0.0374***

Note: this table shows the results of the full model (equation 7). The values of the coefficients and their P-values are shown. ** is placed above the P-value when the coefficient is significant at a significance level of 5%.

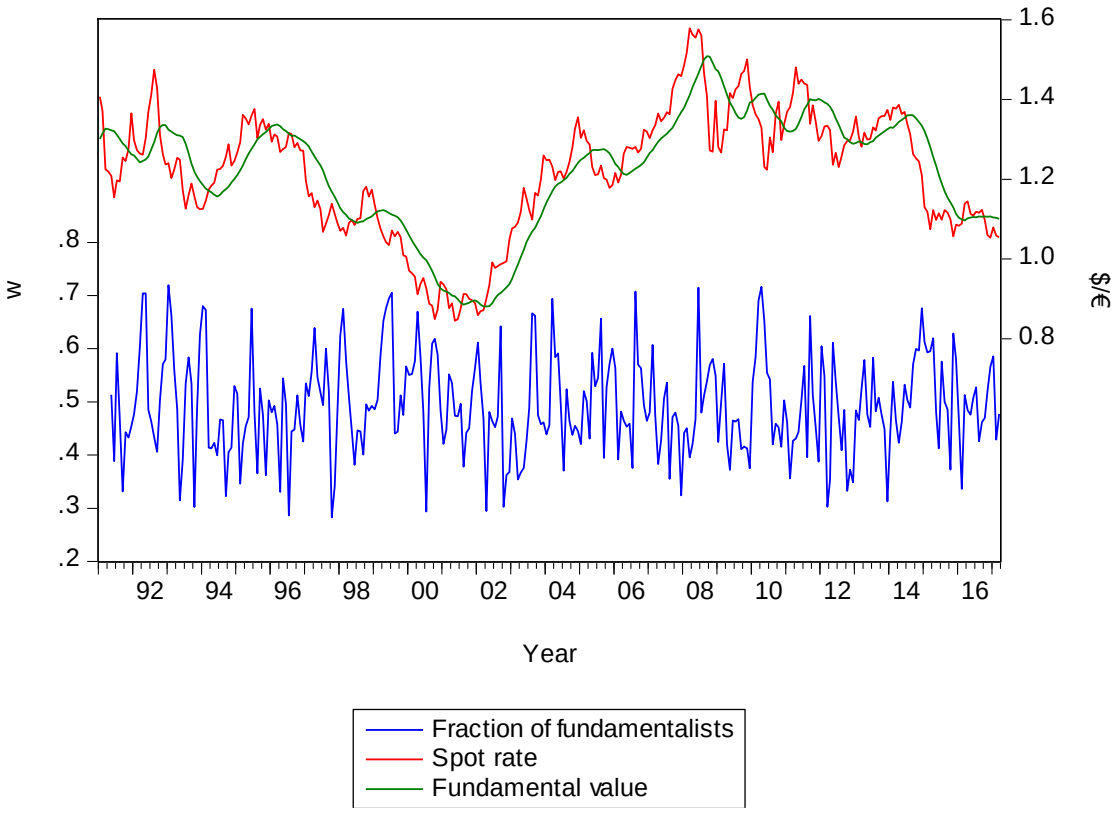
The results in Table 3 are different from the results in Table 2. The intensity of choice parameter, γ, does have a positive value. This means that agents do choose the strategy that performs the best. However, the coefficient of γ is not significant. Just like in Table 2, v_1 and θ_1 both have a negative sign and are not significant. While v_2 was significant in Table 2, it is not anymore in Table 3. The value of v_2 however is still higher than v_1. θ_2 is also higher than θ_1. However, θ_2 remains significant. This means that chartists are the only active agents in the exchange rate market.

5.3 Fundamentalists and chartists over the sample period

The figure in Appendix A shows the graphs of both the USD/Euro exchange rate and the fraction of agents who follow the fundamentalist strategy, ω_t, over the sample period. One would expect that there is a connection between the fraction of fundamentalists and the exchange rate. According to the results shown in Table 2 and Table 3, fundamentalists barely have an effect on the exchange rate. The figure in Appendix A confirms these results. It seems that the fraction of fundamentalists varies randomly over time. However, it is interesting to see

that when the exchange rate decreases, chartists are the most active agents in the market. This also confirms that chartists extrapolate a negative trend. Another observation is that after several periods of decreasing spot rates, the fraction of fundamentalists peaks. During these peak periods of fundamentalists, the spot rate starts to increase again. Huisman et al. (2010) state that the fundamentalist strategy has a stabilizing effect on prices (Huisman, Maliepaard, & Zwinkels, 2010). Figure 2 below confirms this stabilizing effect.

Figure 2: Fraction of fundamentalists over sample period



CHAPTER 6 Conclusion and suggestions for future research

In this study the effect of heterogeneous agents in the exchange market is tested, using a Heterogeneous Agents Model (HAM). This model assumes that the only active agents in the market are fundamentalists and chartists. Agents can switch between the two strategies, depending on the performance of a strategy.

First, the HAM model is tested assuming that agents cannot switch between strategies. The results of this test show that the fundamentalists are not significantly active when the USD/Euro is overvalued. At a significance level of 10%, fundamentalists are significantly active when the currency is undervalued. Chartists are only significantly active after a negative trend. They extrapolate this negative trend into the future.

The second test assumed that there is a possibility to switch to the strategy that preforms the best. The results of this test show that fundamentalists are not significantly active in the exchange rate market. Chartists are only significantly active in the exchange rate market after periods of decreasing spot rates.

Interesting to see is that over time there is a connection between a decreasing spot rate and the number of chartists. In periods where the chartist strategy is the most popular strategy among the agents, the spot rate follows a negative trend. When the number of fundamentalists in the market increases, the spot rate starts to increase too.

This study shows that chartists are significantly active in the exchange rate market. It also shows that fundamentalists have a stabilizing effect on the exchange rate. Unfortunately the model is unable to explain the movements of the exchange rate. It seems like heterogeneous agents only have little effect on the exchange rates. For future research, one could use survey data among active investors in the exchange rate market. This should make it easier to estimate the number of fundamentalists or chartists in the market. If the survey is taken several times per year, it could also be possible to see whether investors do switch between strategies.

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