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Is the Carry Trade strategy an explanation of the Uncovered Interest Parity puzzle?

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Abstract

This paper examines the uncovered interest rate parity (UIP) and extends the analysis in Spronk, Verschoor and Zwinkels (2013) by looking at the UIP between Sweden and the United Kingdom. The flaws of the UIP and the reasons for why it does not seem to hold, has been called the UIP puzzle. The thesis tests if the UIP puzzle can be explained by constructing a heterogeneous agent model with a carry trader and a fundamental trader, trading with the expectation that the UIP holds. The results of the paper show that the UIP puzzle can partially be explained by the existence of carry traders in the market. A positive interest rate differential will impact the currency of the high-interest rate country to appreciate, a movement which is contradictory to what the UIP predicts. For future studies within the topic, researchers should carefully consider what agents that have the biggest impact in exchange rate markets and thereby possibly be included in the model.

Keywords: Uncovered interest rate parity, UIP puzzle, Carry trade.

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1. Introduction

Could it be the case that one of the most prominent theories for explaining exchange rate movements predicts future movements in the wrong direction? For a long time, the Uncovered Interest Parity (UIP) has been under debate. If studying economics at university, it is compulsory for every student to know what the parity means and what it predicts. However, following from recent studies on the parity, it seems like the UIP predicts future movements in the exchange rate in the wrong direction.

The UIP states that between two countries, the currency of the country with the highest interest rate should depreciate to the currency of the country with the lower interest rate. However, recent studies present results that contradicts the theory, saying that, on average, it seems like the currency of the country with the highest interest rate actually appreciates. The discussion has become known as the "UIP puzzle", where researchers are trying to explain why the UIP seems to predict future exchange rate movements in the wrong direction.

Many explanations have been given to explain the flaws of UIP. Some argue that the assumptions of the theory are faulty, whereas others argue that the problem lies in psychological effects meaning that investors require risk premiums for certain investments, while others blame "noise traders" to be too dominant in the market and therefore disrupt rational expectations. One of the explanations is given by Spronk, Verschoor and Zwinkels (2013). Through the creation of a heterogeneous agent model, the authors examine whether carry trading could explain the flaws of the UIP. A carry trader is an investor who borrows money in the low-interest country, converts the money into the foreign currency, puts the money in a government bond and finally converts the money back to the domestic currency. With other words, the carry trader expects the exchange rate to move in opposite direction to what the UIP predicts.

This thesis will test the UIP by looking at the impact of carry traders in the exchange rate market by constructing a heterogeneous agent model in a similar approach as in Spronk et al. (2013). However, in this paper, two modifications will be made. As the paper by Spronk et al. (2013) simulates interest rates, this thesis will use interest rates for Sweden and the United Kingdom. Furthermore, the model will only consist of a carry trader and a fundamental trader, excluding the chartist trader. The fundamental trader trades with the expectations that the UIP condition holds, and the carry trader with the expectation that the exchange rate will move in the opposite direction to what the UIP predicts. Therefore, the thesis aims to compare a simulated exchange rate generated by the model to the results in Spronk et al. (2013), in order to see if the activity of carry traders changes, and if so, how it affects the explanation of carry traders on the UIP puzzle. Additionally, the paper will analyse the differences in results if a model simulates interest rates rather than using interest rates seen in the market.

The results continue to show that the carry trader will impact the domestic country to appreciate in times of a positive interest rate differential. Moreover, the beta value for the interest rate differential is measured at -1.23 and is statistically different from zero, meaning that a positive interest rate differential between the two countries will, on average, force the currency of the high-interest country to appreciate. For future studies, one should look at the importance of different traders in the exchange rate market, and if any of the traders cannot be excluded in a similar model setup.

The thesis will have the following disposition: in the next section, Section 2, a review of the literature will be given. In Section 3, the theoretical framework is presented. Empirical findings are presented in Section 4. In Section 5, the model for generating a simulated exchange rate is explained. In Section 6, the properties of the model are presented. In Section 7, results are analysed and compared to empirical findings. Finally, Section 8 concludes the thesis.

2. Literature Review

To predict future exchange rate movements, is a continuous question for economists, investors and state-level decision makers. Between World War II and the break-down of the former Soviet Union, several economies and states have undergone a process of deregulation in exchange rate regimes. New and open markets have resulted in a rapid increase in the volumes trading in the exchange rate market. As more financial products were invented, for example the fixed income securities and options industry during the 1980s, exchange rates today depend on several different economic fundamentals and new theories can emerge together with new financial products, for the sake of predictability and to foresee movements in exchange rates. Several theories have tried to explain movements in the exchange rate market, in the long term perspective as well as in the short term perspective. One of the parities that aims to explain foreign exchange movements, is the Uncovered Interest Parity (UIP). The UIP states that the expected movement in an exchange rate is given by the difference in interest rates in the previous period between two countries (Chinn and Meredith, 2004). The relationship has been debated in a great amount of papers from the 1980s and onwards. One of the most impactful papers was written by Eugene Fama (1984), where he examined the role of forward rates and how the forward market affects and impacts future movements in the exchange rate. Fama (1984) states that the role of forward rates to predict future spot rate movements is weak. It might even be that the forward rate may predict the future spot market change in the wrong direction (Sarno, 2005). The finding has placed Covered Interest Parity (CIP) and the already mentioned UIP under scrutiny. CIP is an arbitrage relationship which states that the spot price and the future's price are related to the changes in the interest rate differential. If CIP holds, consequently, the forward rate must be an unbiased predictor of future exchange rate changes (Sarno, 2005). However, according to Fama (1984), the forward rate seems to be a biased predictor of future spot rate movements. Therefore, the UIP cannot hold as the expected exchange rate change cannot be explained by only looking at the interest rate differential (Chinn, 2007). The anomaly has been given several names such as the forward premium puzzle, the UIP puzzle and the forward bias puzzle (Miller, 2014, ch.1, p.7). Henceforth, the term UIP puzzle will be used.

Throughout the years, several explanations have been presented in order to answer the question of the UIP puzzle and why it exists. The underlying problem is to evaluate whether the interest rate differential in one period can explain the exchange rate change in the next period. An ordinary least squares regression (OLS), formulated in Chinn (2007), has the following setup: $s_{t+k} - s_t = intercept + \beta(interest rate differential_t) + error term.$

According to the UIP, the beta coefficient (β) for the interest rate differential at time t should be equal to one. Meaning that the movements in interest rates between two countries is the one aspect affecting the exchange rate in the next period, t+k. However, in a meta study by Froot and Thaler (1990), the average beta value appears to be closer to negative unity than to unity, -0.88 to be precise. The result is extraordinary and implies that the currency of the country with the highest interest rate will appreciate, thus generating a profit in both the interest rate differential and in an appreciation of the currency for an investor trading against the UIP (Miller, 2014, ch.1, p.7).

There exist several competing theories to explain why the beta value is different from unity. Fama's (1984) explanation is that a forward rate is given by the expected future movement plus a forward premium, a premium dependent on time variations. Sarno (2005) goes on to say that if investors are risk-averse, then they must require a risk premium, which distorts the UIP assumptions. If investors demand a risk premium, and the risk premium is not a variable in the OLS regression, a problem will occur with serial autocorrelations. The OLS regression will therefore generate inconsistent and biased estimates of beta (Sarno, 2005). Some studies claim that the puzzle only can be seen in different economic conditions and in developed countries (Miller, 2014, ch.1). Chinn and Meredith (2004) argue that earlier studies on the UIP relation are problematic because of the use of short term data. When using long-term data, interest rates with maturities of five to ten years, the beta value is never negative and almost equal to one. Chinn (2007) summarizes the three most prominent theories of the existence of the UIP puzzle: Investors are not rational as assumed by theory, there is a problem with implementing the econometric regression, and the existence of a risk premium. McCallum (1994), on the other hand, argues that the UIP puzzle exists because of monetary policy makers. Policy makers tend to resist fast changes in the exchange rate. If the exchange rate rises, the policy makers will resist the change by implementing an expansionary policy.

The presentation of different explanations can continue. However, in the exchange rate market, a strategy called carry trade has emerged from the UIP puzzle (Galati and Melvin, 2004). If the future exchange rate does not negatively compensate an investor for borrowing in a low-interest country and invest the borrowed capital in a high-interest country, the UIP cannot hold and the investor will make a profit. The strategy has been used to analyse the movements in the foreign exchange market, thus providing an answer to the UIP puzzle (Spronk, Verschoor and Zwinkels, 2013). An exchange rate market consists of several investors with different expectations of future exchange rates. According to Pojarliev and Levich (2008), there are four important ways in how to trade in the exchange rate market. Trades and expectations can be based on value, which means that the investor believes an exchange rate is connected to a specific value given by a theory, such as the UIP or the Purchase Power Parity. Another style is the trend trader, a strategy based on the assumption that the momentum change will continue.

which means that an investor expects an exchange rate to move according to a specific volatility. Consequently, the last investment style is the already mentioned carry trade. Pojarliev and Levich (2010) further argues that the four types of investors, together, can explain the activity in the exchange rate market to a large extent.

According to Frankel and Froot (1990), a heterogeneous agent model (HAM) is particularly efficient in describing exchange rate movements and capture how different agents trade in the market, due to the fact that investors have heterogeneous expectations of future exchange rate movements. A remarkable increase in the volumes trading indicates such expectations exists in the market (Frankel and Froot, 1990). The overall question is how the agents' expectations of future exchange rates impacts the future exchange rate. This question can be evaluated by using a HAM. As the HAM can separate the different agents and evaluate them one at a time, a HAM is especially efficient in analysing which agent dominates the market, hence which expectation of the future it is that dominates the market. Furthermore, by adding agents to a model, the model will be able to generate different characteristics and stylized facts seen in exchange rates (Pojarliev and Levich, 2008).

The HAM in Spronk et al. (2013) differs from other models such as the one in Brock and Hommes (1997) and De Grauwe and Grimaldi (2006) as the model includes a carry trader together with a chartist trader and a fundamental (value) trader. By adding the carry trader, characteristics are now able to be generated differently from only including the chartist and the fundamental investor. However, in this paper, the chartist investor will be excluded. The chartist investor has a tendency to dominate the market, therefore extrapolating the changes seen in the exchange rate market, thus the effect of fundamentalists trading according to the UIP and the carry trader impact will diminish (Spronk et al., 2013). The question is therefore: by excluding the chartist investor, in what way will the results change?

However, studies including a fundamental trader and a carry trader only, is not common. The chartist trader and the carry trader trades typically on the same side of the market. However, the carry trader and the fundamental trader takes, always, opposite sides of the expected changes (Spronk et al., 2013). The effects of these two different expectations will be the results of this paper. By including a chartist trader, the results of how carry traders and fundamental traders impact the market will be smaller. Therefore, the thesis will exclude the chartist trader.

The model in this paper will be a replication of the one proposed in Spronk et al. (2013) with the difference that the chartist trader is excluded and that the interest rates used are based on exchange rate data and not simulated data. The results of the paper will involve a comparison to the accomplishments that can be made by two agents rather than three. The model will serve as a benchmark to empirical results seen in the exchange rate markets. Therefore, the purpose of the paper is to analyse if the UIP relationship holds. Furthermore, by looking at the carry trade strategy, discuss whether the UIP puzzle can be explained by including a carry trader but not the chartist trader to a heterogeneous agent model.

3. Theoretical Framework

There is a wide range of explanations for the parameters that causes exchange rates to move, in the long run as well as in the short run. In the long run, there is empirical evidence that the exchange rate between two countries follows the relative inflation rate between the countries. The implication of this relationship is that if a country has a higher rate of inflation than another country, the currency of the country with the high inflation rate will depreciate with a rate given by the inflation rate differential. The theory is called the relative purchasing power parity (Burda and Wyplosz, 2013, p.149). In the short run, the two most common theories to explain the movements in an exchange rate is the Covered Interest Parity (CIP) and the Uncovered Interest Parity (UIP) (Cuthbertson, 1996, p.260). However, before describing the parities, there is a need to outline how exchange rates can be acquired.

The foreign exchange market consists of two types of deals. An investor can either purchase an exchange rate on the spot market, meaning that the exchange rate is to be delivered immediately and the price is quoted accordingly. The other option is to purchase the exchange rate on the futures market, i.e. the exchange rate is to be delivered in the future for a price agreed on today (Burda and Wyplosz, 2013, p.375). For future contracts, the most common maturities are set between one and six months (Cuthbertson, 1996, p.259). There is a linkage between the price of an exchange rate on the spot market and in the futures market. The relationship can be shown by looking at two investments in two different countries, involving two government bonds and the relative exchange rate changes between the countries. Based on the assumptions of no default risk, full capital mobility and efficient markets, i.e. arbitrage opportunities do not exist continuously, for an investor to be indifferent between buying a bond in the home country or in

the foreign country, the investment must generate the same return. The return on the investment will lead to the following relationship between the spot price and the futures price:

$$\frac{F_t}{S_t} = \frac{1 + r_t^d}{1 + r_t^f} \,.$$

where F_t denotes the futures price and S_t the spot price denominated in the amount of domestic units in terms of foreign currency units, r_t^d the domestic interest rate on the government bond and r_t^f the interest rate of the foreign government bond with the same maturity. The relationship between the two prices will be given by the ratio between the domestic interest rate and the foreign interest rate (Cuthbertson, 1996 p.260).

If the investor invests the money in the foreign government bond, the investor will be facing an exchange rate risk when converting the investment back to the domestic currency. The implication of the relationship above is that by using a futures contract, the investment is riskless. It is riskless because the investor will know beforehand what the conversion rate will be between the two currencies when converting back the money. The relationship is called the covered interest parity. As the investor buys the futures contract, the investment is covered in the sense that the exchange rate risk is eliminated. The relationship can be re-formulated:

$$\left(1+r_t^d\right) = \left(1+r_t^f\right)\frac{F_t}{S_t}$$

which means that an investment in the domestic country, will be equal to an investment in a foreign denominated bond when the price rate is considered. The equation can be approximated to measure percentage term interest rates:

$$r_t^d = r_t^f - \frac{F_t - S_t}{S_t}$$

where the latter term is referred to as the forward premium. The implication of a positive forward premium is that the futures price of the domestic currency in terms of the foreign currency is higher than the spot value. In the case of a stronger domestic currency in the future market than in the spot market, the theory suggests a lower r_t^d than r_t^f leading to equal returns on the investments (Burda and Wyplosz, 2013, p.376).

As explained earlier, the covered interest rate parity results in a riskless investment. However, investing in a futures contract is not an obligation for the investor. If the investor wants to have an exposure to foreign exchange changes, then the strategy would be to buy the foreign currency in the spot market, buy a foreign denominated bond, wait for the bond to mature and then with

the return on the foreign bond, buy back the domestic currency. The new condition is based on the assumption that investors are risk-neutral, meaning that they do not require a risk premium on their investments to be indifferent between a riskless and a risky investment. As explained, the strategy involves buying the foreign currency in the spot market to a value of S_t , and buy back the domestic currency to a value of S_{t+1} . For the no-arbitrage condition to hold, the investment return must be given by the following relationship:

$$1 + r_t^d = \left(1 + r_t^f\right) \frac{S_t}{S_{t+1}^e},$$

for which S_{t+1}^{e} is the expected exchange rate at the end of the investment period. The relationship is called the uncovered interest parity because of the uncovered position towards possible changes, positive or negative, in the exchange rate between the countries. The relationship can be approximated as:

$$r_t^d \approx r_t^f - \frac{S_{t+1}^e - S_t}{S_t} ,$$

where the latter part of the equation presents the expected appreciation of the domestic currency in terms of the foreign currency (Burda and Wyplosz, 2013, p.376).

For an investor to be indifferent between investing in a domestic or a foreign bond, the two investments must yield the same return. If, for example, the interest rate is lower in the domestic country than the foreign, the domestic exchange rate is expected to appreciate. If the condition does not hold, arbitrage opportunities would occur as an investor could buy either one of the bonds, and convert back to the domestic currency which would not move in the opposite direction of what the investor wants, which would yield a return greater than what could be expected from the interest rate differential (Burda and Wyplosz, 2013, p.376).

The implications of the UIP is that the changes in the exchange rates will be explained by the interest rate differential between the two countries. For the UIP to hold, the market must be dominated by risk-neutral investors, founding their expectations on future changes in the UIP relation. In this paper, investors trading based on the UIP condition is called to have a fundamentalist approach. This is an important assumption in the UIP condition. It could therefore be stressed that risk-averse investors nor so-called "noise traders" have a significant impact on exchange rate prices (Cuthbertson, 1996, p.261).

To understand the findings in Fama (1984), the relationship between the CIP and the UIP is crucial. If the two parities hold simultaneously, then the forward rate will be an unbiased predictor of the future exchange rate change. This implies,

$$F_t = S_{t+1}^e$$

This relationship holds under the assumption that investors are risk-neutral (Cuthbertson, 1996, p.264). However, if, as Fama states, the forward rate is a biased predictor of future changes in the exchange rate, then the UIP is biased in predicting future changes in the exchange rate. Consequently, the UIP puzzle is inevitable.

3.1. Carry trade strategy

However, the question concerns how reasonable the assumption is. Furthermore, what would be the consequences if "noise traders" or risk-averse investors have an impact on market prices? The assumption has been analysed in many papers. One of the papers is the study by Spronk et al. (2013). In the paper, the authors analyse if the carry trade strategy can be an answer to the UIP puzzle.

The most common and simple form of carry trade strategy is to borrow in a low-interest country, convert the money into the foreign currency and invest the same amount in the high-interest country. The currency of the borrowing country is called "the funding currency", and the currency of the high-interest rate currency is called "the target currency". A carry trade strategy can also be constructed with buying an exchange rate on the futures market if it is lower than the spot market. The construction is similar to the former strategy (Cavallo, 2006). However, the thesis will continue with the more common construction.

The carry trade strategy can be profitable for two reasons. The first one is given by the interest rate differential between the two interest rates. If the exchange rate stays on the same level during the investment period, then the profit will be given by the interest rate differential. The second one is if the currency of the high-interest rate country has appreciated during the investment period. The case of an unchanging exchange rate during the investment period, is a very unlikely scenario. As exchange rate changes, the carry trade strategy involves a risk. As explained in the theoretical section, an exchange rate acquired in the spot market will always involve the risk that, in the case of carry trade, the low-interest currency will appreciate. (Cavallo, 2006). Therefore, the carry trade strategy is only profitable if the UIP does not hold as carry traders trade in opposite direction of what the UIP predicts.

As the high-interest country appears to appreciate on average (Frankel and Froot, 1990), it is reasonable to believe that investors consider the strategy as a good investment. In a study by Burnside, Eichenbaum, Kleshchelski and Rebelo (2006), who compared the returns from the carry trade strategy between 1977 and 2005, the authors present that the strategy gave a similar return to the S&P500 index during the same period. Furthermore, the authors state that the reason why the strategy is attractive, is not only due to the returns given, but also the relatively low volatility in the returns. The combination of satisfying returns to low volatility, is an important way to measure the attractiveness of the strategy for an investor. In this respect, the paper shows the reasons for why carry traders are common traders in the exchange rate market. However, Cavallo (2006) finds that the transaction costs, measured as bid-ask spreads, is considerably higher for carry trade strategies than for investing in the S&P500. The consequence of this is, indeed, a lower profit, forcing the investor to invest longer in the interest rate assets to compensate for a higher return. Time, however, induces more risk to the strategy. It is therefore important to, when analysing carry trade profits, have an adjustment for risk.

The size of carry traders in the exchange rate market is debated. As the most common transaction involves currency swaps, which is not reported in balance sheets, it is difficult to clearly see the magnitude of the strategy (Cavallo, 2006). Nonetheless, Galati and Melvin (2004) argues that some movements during the early 2000s, are due to increased activity by carry traders, indicating that the strategy is an impactful parameter in the movements of exchange rates. However, the activity can be tracked as the Bank for International Settlements statistics can find footprints of traders in futures positions and transactions in the over-the-counter market. It can be seen in the balance sheets of banks if borrowing or deposits in specific denominated currencies increase or decrease, which can provide useful support when analysing what currencies carry traders use as funding currencies and target currencies (Galati, Health, McGuire, 2007).

Galati and Melvin (2004) find that some countries are more commonly used as funding currencies and other countries typically constitute the target currencies. By looking at ten-year government bonds, funding currencies (low-interest rate countries) are often Japan and Switzerland. The target currencies (high-interest rate countries) are typically represented by countries like the United Kingdom, New Zeeland and Australia. Galati and Melvin (2004) compare the interest rate differential between Australia and the United States in Libor (London

Interbank Offered Rate), which was as high as four percent in 2004. This indicates that substantial profits can be made through the strategy.

In the exchange rate market, the most common type of investor is the so called institutional investor, consisting mainly of pension funds and insurance companies, followed by hedge funds and commodity traders. These agents are typically important players in the foreign exchange market. Over the period 2001-2004, it appears that hedge funds have had an increased impact on exchange rate movements (Galati and Melvin, 2004). Banks, on the other hand, are important players due to the role of being an intermediary, providing loans in the low-interest country and deposits in the high-interest country (Galati et al., 2007).

4. Empirical findings

To examine whether an exchange rate follows the UIP relation or not, a fundamental exchange rate will be simulated based on the UIP and compared to an exchange rate seen in the market. The exchange rate of Sweden (SEK) and the United Kingdom (GBP) will be used, denoting Sweden as the domestic country and the UK as the foreign country. Following from Spronk et al. (2013), the fundamental exchange rate, s_t^* , is given by the UIP condition:

$$s_{t+1}^* = s_t^* \left(\frac{1 + r_t^a}{1 + r_t^f} \right) + \eta_t^* \quad (1)$$

where s_{t+1}^* is the exchange rate in the next period, r_t^d is the domestic interest rate, r_t^f the foreign domestic interest rate, and η_t^* a noise term. The data used for the interest rates is taken from Thomson Reuters Datastream, using daily bid yields from a 1 month government bond in the two countries, between the years of November 1987 and November 2017. The data used for the exchange rate is daily rates presented by the Swedish Riksbank. The 30-year period consists of 7,828 trading days. To add noise to the fundamental exchange rate, the stochastic term, η_t^* , in the fundamental exchange rate is normally distributed and has a mean of zero and a variance of 0.015. The presence of noise traders in financial markets is unquestionable (Black, 1986). However, it could be discussed how large the group is and the impact it has on the foreign exchange market. The variance and mean values are set to include noise traders but only to be a minority in the market.

Figure 1. The upper panel shows the fundamental exchange rate and the exchange rate between the Swedish krona and the British sterling. The lower panel shows the interest rates in the two countries and the interest rate differential.



In Figure 1, the black line in the upper panel represents the empirical exchange rate in the market denominated in SEK/GBP, and the red line represents the fundamental exchange rate according to the UIP. The lower panel presents the interest rates in percentage terms and the interest rate differential between the two countries (orange line, Swedish interest rate minus the UK interest rate). If the UIP would hold, the exchange rate seen in the market would be solely influenced by the movements in the relative interest rate between the two countries and the black line would be equal to the red line. However, this is rarely the case. The only periods when the UIP line corresponds with the empirical data, more or less, is from 1987 to 1989, a shorter period in 1992, around 1996, a shorter time in 2011 and 2012 and then finally at the end in 2017. It appears that the empirical exchange rate mostly is above the fundamental exchange rate, meaning that the Swedish krona is weaker than what appears to be the case if the UIP would determine the exchange rate. Thus, there is a need to question the UIP relationship as it seems like the UIP does not hold between Sweden and the United Kingdom during this period. This implies that there are more investors than the UIP-rational investor active in the market, alternatively that any of the UIP conditions are not met. To analyse the different investment styles and their impact in the exchange rate market, a heterogeneous agent model will be constructed.

5. Methodology

To assess the Uncovered Interest Parity, a heterogeneous agent model (HAM) is created to analyse the movements in the exchange rate. A HAM setup is an appropriate method for analysing how different agents' expectations, all existing in the market, impact the exchange rate (De Grauwe and Grimaldi, 2006). The model which will be used is similar to a model proposed by Spronk et al. (2013). According to the paper by Spronk et al. (2013), the UIP puzzle can be analysed through a model containing different agents, trading in relation to different movements in the exchange rate. A HAM is particularly accurate in replicating stylized facts seen in exchange rate markets such as excess kurtosis, excess volatility and volatility clustering. For the model to be statistically relevant, it is important that the model can replicate the stylized facts (De Grauwe and Grimaldi, 2006). It is then possible to disconnect the UIP puzzle and provide an answer to the movements in the exchange rate.

5.1. The exchange rate market

In this essay, the exchange rate market is represented by two countries: Sweden and the United Kingdom. The Swedish krona and the British sterling are common trading currencies in the exchange rate market (BIS, 2016). Following from section 3.1, the UK is often involved in carry trade setups. However, the Swedish krona is rarely mentioned as a common currency in carry trading. Therefore, the thesis aims to extend the previous carry trade theory by including the Swedish krona, to see if theoretical explanations also hold for currencies that are rarely involved in carry trading activities. Moreover, investments will be viewed from a Swedish-investor perspective. Therefore, as in the previous section, Sweden will be denoted as the domestic country and the UK as the foreign country.

5.2. Model

The agents in the model will be represented by fundamental traders and carry traders. The fundamental trader is trading according to the UIP theory, meaning that the fundamental trader expects the exchange rate to move towards the exchange rate given by the UIP relation. The carry trader will trade against the UIP, expecting the exchange rate of the high-interest rate country to appreciate, rather than depreciate as predicted by the UIP. In relation to other studies using a HAM, this setup emphasises the effects of the carry trader on the exchange rate compared to models like in De Grauwe and Grimaldi (2006) where the carry trader is left out. The difference in this setup compared to the one proposed in Spronk et al. (2013) is that the

chartist trader is excluded. The chartist trader is a momentum trader, meaning that the trader expects the most recent trend to persist. Therefore, a movement upwards or downwards will be extrapolated by the chartist trader. This delimitation of excluding the chartist trader, will impact the results compared to the ones seen in Spronk et al. (2013). It will be negative in the sense that the chartist expectation constitutes an important part of the expectations in the market (Frankel and Froot, 1990). However, as the chartist trader tends to dominate the market more than the two other traders, the impact of carry trading and fundamental trading in the market will be more observable by excluding the chartist trader.

The fundamental exchange rate

The fundamental exchange rate is expected to move according to the UIP relation, as in Frankel and Froot (1990) and Spronk et al. (2013). Spronk et al. (2013) states that the most prominent models used to simulate a fundamental value in a HAM setup is the UIP and Purchase Power Parity, indicating the relevance of using the UIP as the underlying model of the fundamental exchange rate.

Following from the UIP relation, the fundamental exchange rate, s_t^* , is given by equation (1) where s_{t+1}^* is the fundamental exchange rate in the next period, r_t^d is the domestic interest rate, r_t^f the foreign domestic interest rate, and η_t^* a small noise term. Accordingly, the fundamental exchange rate will be determined by the relative changes between the two interest rates. The data used to simulate the fundamental exchange rate will be the same as in section 4. The 30-year period consists of 7,828 trading days. Therefore, the model will be simulated over 7,828 periods. This setup is somewhat shorter than the model in Spronk et al. (2013) using 10,000 simulated periods.

Rules for forecasting the exchange rate

As described earlier, the agents will form their expectations differently. The fundamental trader expects the exchange rate to move towards the fundamental value. The expected exchange rate changes according to the fundamentalist trader, $E_{F,t}(\Delta s_{t+1})$, is given by:

$$E_{F,t}(\Delta s_{t+1}) = \alpha(s_t^* - s_t) \quad (2)$$

where s_t is the current simulated exchange rate and α is a positive parameter which denotes the speed of which the trader expects the exchange rate to move towards the fundamental exchange rate. For the fundamental trader to have the correct expectations, the parameter α must take a value in the interval of $0 < \alpha \le 1$.

The carry trader's expectations will be the opposite of the fundamentalist trader. The interest rate differential is the key component, which makes the expected exchange rate change for the carry trader, $E_{CT,t}(\Delta s_{t+1})$, to look like:

$$E_{CT,t}(\Delta s_{t+1}) = -\gamma \left(r_t^d - r_t^f \right) \quad (3)$$

where γ represents the preferences of the carry trader of how much the interest rate differential will affect the exchange rate. Consequently, for the carry trader to have the correct expectations, the parameter γ must be bigger than zero. Equation 3 is in line with the theory of the carry trader, saying that if the interest rate differential is positive, then the trader can make a profit by borrowing in the low-interest country, convert the money to the high-interest country currency and invest the money. The outcome will involve a higher demand for the high-interest rate country, hence an appreciation of the currency of the high-interest rate country. This movement is captured by the minus sign in the first part of the equation.

To summarise the two investment strategies in the model, it is clear that the carry trader and the fundamental trader will trade in opposite directions depending on the interest rate differential. If, for example, the domestic country has a higher interest rate than the foreign country, the exchange rate is expected to depreciate according to the fundamental trader and appreciate according to the carry trader. They have complete opposite expectations of future exchange rate movements.

Weights of profits and changing between strategies

In the model, agents can switch between the different strategies. The switching between strategies will be determined by the profits that the strategy has made in the previous period. The profits of the specific strategy will be given by:

$$\pi_{i,t} = \left[s_t \left(1 + r_t^f\right) - s_{t-1} \left(1 + r_t^d\right)\right] sign\left[\left(1 + r_t^f\right) E_{i,t-1}(s_t) - \left(1 + r_t^d\right) s_{t-1}\right]$$
(4)
where i = F (fundamentalist) and CT (carry trader). Thus, the profit will be given by investing
one unit of the foreign currency. The sign is determined by whether the agent expected the
movement in the exchange rate correctly:

$$sign(x) = \begin{cases} 1 \ if \ x > 0 \\ 0 \ if \ x = 0 \\ -1 \ if \ x < 0 \end{cases}$$

To get profits adjusted for risk, the following modification will be made:

$$\pi'_{i,t} = \pi_{i,i} - \mu \sigma_{i,t}^2$$
 (5)

where $\sigma_{i,t}^2$ is the amount of risk measured by the difference in expected exchange rate to the outcome and μ a parameter representing the level of risk aversion. By using risk-adjusted profits, the model can capture the risk that the investor may forecast the exchange rate incorrectly. The risk $\sigma_{i,t}^2$ is given by:

$$\sigma_{i,t}^2 = (E_{i,t-1}(s_t) - s_t)^2 \quad (6)$$

In order to determine the market expectations based on past performance, a switching rule must be formulated. The weights of the two strategies in the market will be determined by the profit π'_i . Consequently, for an agent to choose between the strategies based on the performance in the previous period, the weights will be calculated as:

$$w_{F,CT} = \begin{cases} \frac{\exp\left(\varphi\pi_i'\right)}{\exp(\varphi\pi_F') + \exp\left(\varphi\pi_{CT}'\right)} & (7) \end{cases}$$

where φ is a parameter bigger than zero, representing how fast an agent is prepared to switch between two strategies. Consequently, a value of $\varphi=0$ would mean that investors are not willing to change strategy regardless of past profit performances, whereas $\varphi \to \infty$ implies that investors are willing to switch strategies completely even if the difference in profit generated between the strategies is extremely small. In this case, investors of the market would use the superior strategy at all times. The outcome of this step will show which strategy that will dominate the market.

The final step

The final step before the model is ready to be used is to summarize the weights and the expected change for the different strategies. The expected change, $E_t \Delta s_{t+1}$, is given by:

$$E_{t}\Delta s_{t+1} = \sum_{i=F,CT} (w_{i,t}E_{i,t}(\Delta s_{t+1}))$$
(8)

where $w_{i,t}$ represents the weights of the two strategies in the market at time t. The exchange rate will thus depend on the weighted expectation of an agent, representing how the market expects the exchange rate to move. It is assumed that the expected change equals the realized change. For the exchange rate to include noise traders in the market, a normally distributed noise term is added which gives the last equation of the simulated exchange rate change, Δs_{t+1} : $\Delta s_{t+1} = E_t \Delta s_{t+1} + \eta_t$ (9).

5.3. Choosing parameters

The exchange rate generated by the model is highly dependent on the parameters described in the previous section. The choice of the used parameters is based on the approach by Spronk et al. (2013). However, a final re-calibration was necessary due to the differences in the model, in order to replicate the effects and patterns observed in the exchange rate market and also to avoid negative exchange rates.

Parameter	Value	Explanation
α	0.2	Speed of movement
γ	0.7	Carry trader preference
φ	10	Switch velocity
μ	1	Risk aversion

Table 1. The selection of parameters in the model.

6. Results

6.1. Properties of the model

The model is simulated over 7,828 periods, from November 1987 to November 2017, where one period is set to one day. The stochastic term, η_t^* , in the fundamental exchange rate is normally distributed and has a mean of zero and a standard deviation of 0.13. The stochastic term, η_t , in the final step of the model, is expected to have a mean of zero and a standard deviation of 0.17. The simulated exchange rate, the exchange rate based on the UIP condition and the exchange rate between the Swedish krona and the UK pound, is shown in Figure 2. Figure 2. The upper panel displays the simulated exchange rate, the fundamental exchange rate and the exchange rate given by data. The middle panel shows the weights of investors who are active in the market, where the blue line shows the fundamental investors. Finally, the bottom panel displays the interest rates and the interest rate differential.



The simulated exchange rate generated by the model, the blue line in the upper panel, shows features that appear in the exchange rate market. The simulated exchange rate follows the fundamental exchange rate to a large extent. However, sudden drops in the simulated exchange rate can be seen four times in the figure. These sudden drops are commonly known as bubble phases. Bubble phases are a recurring theme in exchange rate markets (Spronk et al., 2013). The bubble phases that can be seen takes places in the first year of the investment period, from 1992 to 1995, in 2011 and finally in 2013. There are two mutual denominators during the bubble phases. First of all, which can be seen in the bottom panel, is that the interest rate differential is positive when these phases occur. A positive interest rate differential implicates that the carry trade strategy becomes profitable and the weights of the carry traders will become active, which leads on to the second denominator. The second denominator is the fact that during the bubble phases, carry traders fully dominate the market, which can be seen in the middle panel.

Along with bubble phases, it appears that the simulated exchange rate tends to move towards and in collaboration with the fundamental exchange rate. The tendency is displayed during the times of a negative or a low interest rate differential, such as the longer period from 1996 to 2011. During these phases, the middle panel shows that the fundamental trader is more active in the market. It is during these periods that the fundamental trader is able to predict the exchange rate movement in the next period correctly. When the trader correctly predicts the future movement, the trader is on the right side of the market, thus generating a higher profit and therefore a higher weight of fundamental traders in the market. At the same time, the interest rate differential is too low for the carry trade strategy to be profitable, as these traders will switch to the fundamental strategy.

6.2. The effect of interest rates

Intuitively, interest rates impact the simulated exchange rate in two ways. As the fundamental exchange rate is, except of a small noise term, dependent on the differences in the relative interest rates between the countries, the fundamental exchange rate will move in relation to interest rate movements. From equation 1, it is understood that as the domestic interest rate increases in relation to the foreign, the fundamental exchange rate will increase i.e. the Swedish krona will depreciate to the UK pound. This is, as stated in the theoretical section, predicted by theory. In the simulation, it can be seen that when the interest rate differential increases, the fundamental exchange rate slightly increases, i.e. the Swedish krona depreciates to the UK pound. This is displayed from 1992 to 1996; the fundamental exchange rate slowly increases during this phase. The opposite relationship occurs when the interest rate differential decreases which makes the fundamental exchange rate to decrease i.e. the Swedish krona appreciates to the UK pound. This can be seen in the period from 1996 to 2008.

The second way in which interest rates impact the exchange rate, is through the profitability of the carry trader strategy. The condition for the carry trade strategy to be profitable, is a positive interest rate differential. As explained earlier, this is displayed in the simulation in the first part around 1988, a longer period from 1992 to 1995, in 2011 and finally in 2013. A positive interest rate differential makes the carry trade strategy profitable and the strategy will therefore dominate the market.

6.3. The carry trade impact

An important observation in the simulation, is to see the effects of an exchange rate market dominated by carry traders. In the simulation, the middle panel demonstrates that carry traders dominate the market in parts of 1988 (1), the interval between 1992 and 1995 (2), in 2011 (3) and finally in 2013 (4). During these intervals, the investors influence the exchange rate to decrease (appreciation of the Swedish krona). The results are contradictory to the UIP theory. When the interest rate in Sweden is greater than in the UK, the Swedish krona is expected to

depreciate to compensate for a higher interest rate. This is due to the profitability of the carry trade strategy, which increases when the interest rate differential increases. Intuitively, this is reasonable due to the fact that the carry trader will make a profit when the exchange rate moves in the opposite direction as the UIP condition predicts. During the periods of a positive interest rate differential, the exchange rate should increase according to the UIP condition. However, as the carry trader dominates the market, the exchange rate will move downwards when the strategy becomes profitable. The carry trader will make a profit in two ways. Firstly, as the investor borrows money in the low-interest rate country and invests the money in the highinterest country, the profit will be given by the interest rate differential. The UIP states that this profit should be negatively compensated by a movement in the exchange rate. Secondly, as the exchange rate moves in opposite direction of what the theory predicts, the investor will, also, make a profit from converting the two exchange rates. A market dominated by carry traders will, therefore, have a substantial negative impact on the exchange rate, thus causing the Swedish krona to appreciate. However, as the interest rate differential decreases, the profit generated by the carry trade strategy becomes lower and the exchange rate will depreciate, i.e. increase as fundamental traders will enter the market.

6.4. Time variation in profits

The periods of carry trade domination are equivalent to the following dates:

Interval	Time
1	1988
2	1992 - 1995
3	2011
4	2013

Table 1. Carry trade domination.

According to Briére and Drut (2009), the carry trade investment possibilities are dependent on economic conditions, and the investment profit will be substantially lower in periods of a crisis. Additionally, according to Spronk et al. (2013), there should be time variations in investment profitability. Table 1 gives an overview of when carry traders dominated the market, thus when the strategy was profitable. The model does not show any signs that a specific economic condition would be more suitable for a carry trade investment, as stated by Briére and Drut (2009). The banking crisis in the early 1990s in Sweden caused interest rates to surge. In our model, this would be a signal to carry traders to enter the market. However, it does not seem to

be the case as the SEK/GBP depreciated (increased) in 1992 which would indicate that investors with different expectations than the carry traders would dominate the market at the time. Moreover, the financial crisis of 2007-2008 does not seem to have any particular effect on carry trade profitability. Initially, interest rates in both countries dropped rapidly in 2008. The Swedish interest rate then increased slightly while the UK interest rate remained constant. This lead to a positive but small interest rate differential and thus the entrance of carry traders in the model, until the Swedish Riksbank decided to decrease the interest rate once again.

7. Results and Analysis

7.1. Statistical properties

To examine whether the model corresponds with empirical results, the thesis will analyse three statistical properties: heavy tails, excess volatility and volatility clustering in exchange rate returns. These stylized facts are persistent themes in the exchange rate market (Lux and Marchesi, 2000; De Grauwe and Grimaldi, 2006). For the model to have an empirical relevance, the model should be able to replicate these stylized facts. Therefore, the properties generated by the model will be compared to the stylized facts seen in the market. Values of the stylized facts can be seen in Table 2. It should be noted that this section does not aim to give a detailed explanation of the stylized facts, but rather to let the facts serve as a comparison between the model and empirical findings.

The returns of the exchange rate will be approximated by taking log-returns. In financial analysis, calculating the returns with log-differences between the exchange rate value in time t and the value in the next period, t + 1, is a common method (Kanas and Karkalakos, 2017). However, it should be said that the log-return-method is not flawless as log-approximation is only a valid method when the returns of the exchange rate are small. Nevertheless, it could be argued that this assumption holds for exchange rate returns (Kanas and Karkalakos, 2017).

Table 2. Statistical properties of the returns of the exchange rate simulated by the model and the returns of the exchange rate given by data.

Stylized fact	Returns _{simulation}	Returns _{data}
Kurtosis	11.4769	13.3424
Skewness	-0.2205	0.1667

Excess volatility	12.6838	8.0318

Heavy tails: excess kurtosis and skewness

According to Huisman, Koedijk, Kool and Palm (2002), the distribution of foreign exchange returns tends to be non-normal, instead they have fat tails. To test if the model generates fattailed returns, the kurtosis value is calculated as fat tails can be measured through excess kurtosis. A distribution is defined to have excess kurtosis if the kurtosis value is larger than three (Spronk et al. 2013).

Kurtosis is a fourth order moment of the probability distribution. It is measured as:

$$Kurtosis = \frac{E(X-\mu)^4}{\sigma^4} \qquad (10)$$

where μ is the mean of X, σ the standard deviation of X and $E(X - \mu)$ the expected value of the quantity function. Following from equation 10, skewness is a third order moment of the probability distribution which is calculated as:

Skewness =
$$\frac{E(X-\mu)^3}{\sigma^3}$$
 (11).

From Table 2 it is presented that the kurtosis for the simulated exchange rate returns is 11.48 while the returns on the market have a kurtosis of 13.34. In the study by Huisman et al. (2002), the authors calculated kurtosis values for returns between several currencies to the UK pound between 1979 and 1996. The authors presented statistics that showed that all currency distributions for exchange rate returns in relation to the UK pound exhibited fat tails. Nevertheless, between the Swedish krona and the UK pound, excess kurtosis was evident during the period. As the kurtosis value generated by the model was greater than three, it is showed that the simulation can produce fat-tailed returns. This indicates that, in terms of replicating heavy tails successfully, the model is empirically relevant, which also is confirmed in the study by Huisman et al. (2002).

The model generated a skewness of -0.22 whereas the skewness seen in the market was positive, 0.17, which can be seen in Table 2. According to Briere and Drut (2009), an exchange rate market where carry traders are more dominant should generate a more negative skewness and a higher kurtosis. The same reasoning can be seen in Spronk et al. (2013) where a larger weight of carry traders in the market leads to a more negatively skewed return distribution. In the model

by Spronk et al. (2013), when interest rates are modelled to make it more difficult for carry traders to enter the market, the returns become more positively skewed as carry traders cannot influence the currency to appreciate (decrease). For the model to generate returns similar to the ones seen in the market, the distribution should have been skewed positively (to the right). As the model was not able to generate a positive skewness, this indicates that the model gave carry traders too much of an impact in the model, leading to a negative skewness which empirical findings do not support.

Excess volatility

De Grauwe and Grimaldi (2006) discuss the fact that the volatility for exchange rates are much more volatile than the underlying economic fundamentals. Excess volatility is defined, as in De Bondt and Thaler (1990) and Spronk et al. (2013), as the volatility in the exchange rate that is not captured in the fundamental exchange rate. In other words, if the fundamental investor is assumed to have rational expectations, the volatility in the exchange rate exceeding this is said to be excess volatility. Thus, the excess volatility is measured by:

$$Excess \ volatility = \frac{Volatility_{exchange \ rate} - Volatility_{fundamental}}{Volatility_{fundamental}}$$

Volatility is measured as the variance of the data. The variance, denoted as σ^2 , will lead to the equation for excess volatility:

Excess volatility =
$$\frac{\sigma^2_{exchange rate} - \sigma^2_{fundamental}}{\sigma^2_{fundamental}} \qquad (12).$$

The excess volatility is measured in relation to the volatility in the fundamental exchange rate. The excess volatility is displayed in Table 1, showing that the simulated exchange rate has an excess volatility of 12.68 and the exchange rate seen in the market has an excess volatility of 8.03. An excess volatility of 12.68 is considerably smaller than compared to the excess volatility generated in the model by Spronk et al. (2013). It is the chartist trader that extrapolates the movements created by the carry trader that generates a higher excess volatility similar to what is seen in the market. As the simulated exchange rate has a volatility of 12.68, it is much closer to the excess volatility seen in the market compared to what the model in Spronk et al. (2013) generated.

Volatility clustering

The third stylized fact to be analysed is the tendency for changes in exchange rate returns to be followed by even larger changes, a phenomenon called volatility clustering (Lux and Marcesi, 2000). To test if the model can replicate volatility clustering, the autocorrelation function of absolute returns is plotted in Figure 3 for the simulated exchange rate and in Figure 4 the autocorrelation function of absolute returns for the exchange rate seen in the market.

The autocorrelation function measures the correlation between the absolute return in period t and the absolute return in period t+k, where k is the number of lags in the sample (k = [0, 100]). This means that the returns in the first lag (when k = 0) will have an autocorrelation of 1, as it is fully correlated with itself. As absolute returns are measures of the volatility, the thesis will examine if the volatility can show signs of memory over time, where time is represented as the number of lags.

Figure 3. Autocorrelation function of absolute returns for the simulated exchange rate.



Figure 4. Autocorrelation function of absolute returns for the exchange rate given by data.



The blue lines in the two figures represent the 5% significance levels for the autocorrelations. In both figures, the autocorrelation function of absolute returns declines when the number of lags increases. It implies that there is a memory in volatility of absolute returns. Additionally, it is understood that the volatility is greater at times and lower at other times, implying that the simulated exchange rate and the exchange rate in the market are sometimes volatile and sometimes calm. A result that is reasonable. The autocorrelation function of absolute returns in the model (Figure 3) is fairly close to the one seen in the market (Figure 4). Therefore, it is showed that the model can generate returns that show volatility clustering similar to what is seen empirically in the market.

7.2. Model discussion

The model proposed in this paper is inspired by the model used in Spronk et al. (2013). However, in this thesis the model is only a simplified version as the chartist trader is excluded. The chartist trader expects that the latest trend in the exchange rate will continue, therefore extrapolating all the movements in the exchange rate. The model in this paper was not able to generate a result where the simulated exchange rate, for a longer time, stayed above the fundamental exchange rate. This is due to the fact that when the exchange rate is close to the fundamental exchange rate, there is no profit to be made by the carry trader, thus the fundamental trader will be the only trader to dominate the market. The interaction between a chartist trader and a carry trader would probably have solved this problem. A chartist trader would impact the exchange rate to show more dynamic changes, forcing the exchange rate to increase over the fundamental exchange rate (Spronk et al., 2013).

As the model successfully replicated most stylized facts and generated results that are similar to what is seen in the exchange rate market, the construction of a heterogeneous agent model was, empirically, a correct methodology. The empirical relevance is one of the reasons for choosing a heterogeneous agent model when aiming to replicate an exchange rate market (De Grauwe and Grimaldi, 2006).

7.3. Critique of Spronk et al. (2013)

In the paper by Spronk et al. (2013), the chartist trader dominates the market, with the consequence that the simulated exchange rate hardly moves below the fundamental exchange rate. A model that cannot replicate a simulated exchange rate below the fundamental exchange rate, is flawed. Additionally, there is a risk that the chartist trader will have too much of an impact on the market, minimising the possibility to see the effects of the carry trader.

The paper by Spronk et al. (2013) argues that carry traders mostly trade between high and lowinterest rate countries as described in the first section. When comparing the interest rates between the domestic (high) and foreign (low), there is hardly ever a negative interest rate differential. However, to evaluate if the UIP holds, different countries with sometimes high and sometimes low interest rates must be examined to see how the UIP relation stands in different economic environments, like in the case of Sweden and the United Kingdom. If a model only consists of a high-interest domestic country and a low-interest foreign country, then carry traders will of course have a significant impact on the exchange rate market. The assumption that carry traders often appear in these environments seems plausible. Nevertheless, the UIP theory does not state that the relationship only holds for countries with a low interest rate differential.

7.4. Explaining the forward premium puzzle with Carry traders

To answer the question whether the carry trade strategy can solve the UIP puzzle, the regression in the second section will be constructed. Following from Spronk et al. (2013), the ordinary least squares regression is formulated as:

$$s_{t+22} - s_t = \alpha + \beta (r_{t+22}^d - r_{t+22}^f) + \varepsilon_{t+22}$$

where the change in the exchange rate for 22 periods ahead, $s_{t+22} - s_t$, is the dependent variable, α the intercept, β the interest rate differential coefficient at time t+22, and ε an error term. r_{t+22}^d and r_{t+22}^f are daily measures of one-month interest rates and the investment horizon is set to one day. One month is equal to 22 trading days. This implicates that the interest rate differential will determine the exchange rate change for 22 periods ahead. Due to overlapping regressions in the time series data, standard errors are corrected for autocorrelation by using the Newey-West estimator. The values of the parameters are displayed in Table 3 and Table 4. *Table 3. Regression for the simulated exchange rate.*

Coefficient	Value	p-value	t-statistics
α	-0.0070	0.7605	-0.3049
β	-1.2273	0.0394*	-2.060

Table 4. Regression for the exchange rate given by data.

Coefficient	Value	p-value	t-statistics
α	-0.0023	0.8419	-0.1995
β	-0.7087	0.0776	-1.765

According to the UIP theory, the intercept value, α , is expected to be zero and the interest rate differential, β , should be equal to one. As Table 3 shows, the regression has an intercept value which is not statistically different from zero. However, β has a negative coefficient of -1.23 and is statistically significant from zero with a confidence level of 95%. This implies that the direction of carry trader impact on the market, which is negative, is statistically proven. The value is considerably lower than the one found in Spronk et al. (2013), which is -0.40 and also lower than the one found in Froot and Thaler (1990), which was -0.88.

In Table 4, the regression estimates are presented for the exchange rate seen in the market. As for the intercept value, α , the value is not statistically significant from zero which is in line with

the theory. The β -value however, is negative and statistically significant from zero on a confidence level of 90%. The measured value is not as low as the one found in Froot and Thaler (1990), but more like the one found in Spronk et al. (2013).

The regression shows that the carry trade strategy might be a possible explanation for why the UIP relation does not hold. It is shown that if the market consists of traders with expectations similar to the carry trade expectation and a positive interest rate differential occurs, the strategy will generate a positive profit and in so leading to an appreciation of the currency with the higher interest rate. This phenomenon violates the uncovered interest rate parity. An explanation for why the beta value for the regression of the simulated exchange rate was lower than what other papers found, is because of the opportunities given to carry traders. In models such as in Spronk et al. (2013), the carry trader domination is considerably lower, meaning that the interest rate differential is not as negatively impactful as in this model.

To explain the UIP puzzle fully, the carry trade explanation is simply not enough. Nevertheless, it provides a good indication of the expectations in the market, and should therefore perhaps be included in courses in economics at universities.

8. Conclusion

To conclude, the thesis shows that the carry trade strategy can be an explanation to the UIP puzzle, therefore giving support to the conclusions in Spronk et al. (2013). The exchange rate generated by the model corresponds, to a large extent, with empirical results. However, for a heterogeneous agent model to generate results similar to empirical patterns, one ought to investigate if the chartist trader should be included in the model. The most probable explanation for why the UIP does not hold, is the interaction between carry traders and chartists, as proposed in Spronk et al. (2013). However, it must also be said that the existence of chartist traders in a model minimises the impacts of the carry traders. For future studies on the UIP puzzle with heterogeneous agent models, it should be carefully examined whether the chartist trader should be included or not in the model. If an important trader is left out, results might still be generating a negative beta value, as in this thesis, but run the risk of being empirically irrelevant. A model must be calibrated with care so that the impact of carry traders can be seen but not being fully dominated by either carry traders nor chartist traders.

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