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„Liquidity in FX-Markets

An analysis of the US-BRICS Exchange Rates"

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Patrick Plum, BSc

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Abstract

In this thesis the results of an empirical research on the interplay of real interest rates and exchange rates for the BRICS countries relative to the US for the period from 2007 to 2017 are presented. A vector error correction model is applied in order to provide ex ante estimates of inflation. The results reject the hypothesis of uncovered interest parity and suggest that the connections of interest rates and exchange rates in emerging economies are rather country specific as well as depending on global market conditions after the financial crisis. The impact of liquidity on interest rates and exchange rates in the BRICS countries is dicussed and it is explained how spillover effects from quantitative easing in the US might account for the empirical findings.

Keywords: Interest Parity, BRICS, Liquidity, Interest Rates, Exchange Rates, Vector Error Correction Model, Quantitative Easing

Übersicht

In dieser Masterarbeit werden Ergebnisse einer empirischen Untersuchung des Zusammenspiels von realen Zinssätzen und Wechselkursen der BRICS-Länder in Relation zu den USA in der Zeit von 2007 bis 2017 präsentiert. Um ex-ante Abschätzungen der Inflationsraten zu erhalten, wird ein Fehlerkorrekturmodell angewandt. Die Ergebnisse widersprechen der ungedeckten Zinsparitätentheorie und lassen darauf zurückschließen, dass es landesspezifische Zusammenhänge zwischen Zinssätzen und Wechselkursen in Schwellenländern gibt und diese auch von globalen Marktbedingungen nach der Finanzkrise abhängen. Der Einfluss von Liquidität auf Zinssätze und Wechselkurse der BRICS-Länder wird evaluiert und es wird gezeigt, wie externe Effekte der quantitativen Lockerung in den USA die empirischen Ergebnisse erklären können.

Keywords: Zinsparität, BRICS, Liquidität, Zinssätze, Wechselkurse, Fehlerkorrekturenmodell, Quantitative Lockerung

Contents

1. Introduction

1.1. Background

In 1971, the Bretton-Woods era of fixed exchange rates came to an end and many countries changed to a system of floating currencies. This raised the question of how exchange rates for this floating currencies are determined. Early theories, like the Mundell-Fleming Model, or the Overshooting Model of Dornbusch (1976), suggested a strong connection of exchange rates to interest rates in different countries. These theories were built on the idea of interest parity. Interest parity suggests that the interest rate differential between two countries should equal the difference of the exchange rates over the period of the interest.
There is strong empirical evidence that covered interest parity (i.e. the interest differential equals the difference of forward rate and current spot rate) does hold, see e.g. Taylor (1987). This observation clearly reflects the fact that the foreign exchange market is a market with high liquidity and low transaction costs and covered interest parity is often considered as a no-arbitrage condition. On the other hand, there is plenty of literature that provides empirical evidence that the uncovered Interest Parity (i.e. the interest differential equals the differential of future spot rate and current spot rate) does not hold. This became known as interest parity puzzle or forward premium puzzle and one of the early papers to provide evidence for this finding was Fama (1984). In this paper the difference between future spot rates and forward exchange rates, i.e. the forward premium, has been investigated for nine major currency pairs of industrialized countries. One of the main findings has been that there is a negative correlation between expected future exchange rates and the forward premium.

While for developed economies the findings of the uncovered interest parity puzzle are well known, it is also of interest if findings can be reproduced for countries showing different characteristics than the industrialized ones. Bansal and Dahlquist (2000) were performing research on the uncovered interest parity puzzle on a sample of industrialized and emerging countries. One of their main findings was that the uncovered interest parity puzzle is particularly evident in situations when the interest rates of an industrialized country falls below that of the US. For emerging countries, however, the puzzle has not been clearly evident. Another paper to this topic is Flood and Rose (2002), where countries which were suffering from crises in the 1990s and those which were not are compared. Their key finding is that uncovered interest parity is rather a crisis-induced phenomenon while the interest parity puzzle is more evident in stable economic situations, independently of the country investigated being an emerging or a developed one.

While the interest parity puzzle in the papers above is observed in nominal terms, it is also important to investigate the puzzle in real terms. Results of empirical research in real terms can be directly compared to predictions of economic theories which are often making use of real rather than nominal values. A further advantage is that emerging and developed countries can be compared better in real than in nominal terms.

Literature on uncovered interest parity in real terms is less common. Meese and Rogoff (1988) have observed the linkage between real exchange rates and real interest rates but do not find significant evidence of an impact of the latter on exchange rate volatility.

Another interesting relationship concerning the real exchange rate is given by the empirical observation that real exchange rates seem to show more and more persistent volatility with regards to shocks than most models can explain. This is often referred to as real exchange rate puzzle. Evidence for this finding is presented in Hausmann, Panizza, and Rigobon (2006) which appears to be particularly strong in emerging countries.

In Hau (2002) the relationship of openness of an economy and exchange rate volatility is investigated and a significantly negative correlation has been observed. The role of openness on exchange rates, however, is not further investigated in this thesis.

The recent article of Engel (2016) shows evidence that exchange rates between major industrialized economies show a pattern of an initial underreaction but a delayed overshooting of the exchange rate when it comes to a shock in the interest rate differential relative to the US. He also provides a model that shows how preferences of rational investors with regards to liquidity can explain both of these findings, the classical interest parity puzzle as well as the delayed overshooting of exchange rates.

1.2. Objective

The objective of this thesis is to investigate the interplay of interest rates and exchange rates in the BRICS countries for the period of 2007 to 2017 and to evaluate how liquidity effects might account for the empirical observations.

The second chapter of this thesis is an empirical research on uncovered interest parity and long term persistence of the real exchange rate. It follows the statistical methods which were applied in Engel (2016). The behavior of exchange rates of the 'BRICS' countries Brazil, Russia, India, China, and South Africa to the US-Dollar is analyzed. The aim is to investigate the relationship between interest rates and exchange rates for the BRICS countries. As the data, the research is performed with, cover about the last decade, starting in 2007, it is of particular interest to also observe patterns of exchange rates and interest rates in a crisis-driven environment. In order to be able to compare the results to the behavior of exchange rates and interest rates between developed countries, the same statistical method is performed on the 'G6' countries Canada, France, Germany, Italy, Japan, and the UK as well. The research is performed on nominal values first. Then, including data on consumer price indexes and applying a vector error correction model, the behavior of exchange rates is investigated in real values. This is of particular interest, as economic models often assume interest parity to hold in real terms. The results of the research are compared to those of the literature but especially to the results of Engel (2016).

In the third chapter, it is discussed how liquidity effects can account for findings regarding the interplay of exchange rates and interest rates in real terms. First, a model which includes liquidity preferences, introduced in Engel (2016), is discussed. Then, considering the circumstances within the observed time frame, a possible explanation for the empirical findings of this thesis is provided by discussing the response of the central banks in the BRICS countries to the strong liquidity effects deriving from quantitative easing in the US.

The fourth chapter concludes the results and provides an outlook for further research.

2. Empirical Research

2.1. The Data

The data used for the empirical research are nominal interest rates, exchange rates and consumer price indexes from the US, and the BRICS countries consisting of Brazil, Russia, India, China and South Africa. For comparison, similar data is also used for the G6 countries Canada, France, Germany, Italy, Japan, and the United Kingdom. The period of the data is similar for each country and ranges from October 2007 to May 2017. In the research for nominal values, monthly data is taken, while for that in real terms weekly observations are used. The first datapoint for the weekly observations is the 1st of October 2007, the last is the 29th of May 2017. The monthly observations already stop in April 2017.

The interest rates are taken from Datastream (2017) and cover the timeseries TPBRL1M, TPRUB1M, TPINR1M, TPCNY1M, TPZAR1M which reflect interest on 1-month cash deposits in the BRICS countries. The interest rates for the US as well as the G6 countries are 1-month Eurocurrency deposits of the timeseries ECUSD1M, ECCAD1M, ECEUR1M, ECJAP1M, and ECUKP1M. Thus, because France, Germany, and Italy share the euro as common currency for the whole period covered, they do not have individual interest rates. It would be preferable for the BRICS countries to also use Eurocurrency deposits for the research, as these accounts might yield an easier access for international investors who are active in the foreign exchange market. Since timeseries for Eurocurrency deposits are available for South Africa only, the research is performed on 1-month cash deposits in order to be able to better compare the results for the BRICS countries among each other.

The exchange rates are given as the BRICS or G6 countries currency per US-Dollar and are taken from Datastream (2017) as well. These inlcude the timeseries BRACRU$, CISRUB$, INDRUP$, CHIYUA$, COMRAN$, CNDOLL$, EUDOLLR, JAPAYE$, and UKDOLLR.

The consumer price indexes for all countries including the United States are used in order to measure inflation. The data is taken from the homepage of the OECD, 2017 and is given for each month as percentage to a baseline of 100% which is the Consumer Price Index of 2010 for each individual country.

The monthly data of the period from October 2007 to May 2017 yield 115 observations for each time series. In a first empirical analysis this turned out to be too little information for obtaining robust results in the analysis in real terms. Thus, 505 weekly observations of nominal exchange rates and nominal interest rates are used for the empirical analysis in real terms.

As consumer price indexes are available for monthly but not for weekly data, additional observations are created via interpolation. Consumer price levels gradually adjust over the months for all the observations taken and do not show huge volatility. Thus, an interpolation with a spline seems to be reasonable despite yielding the penalty of obtaining a small error. In detail, for each country monthly observations from October 2007 to June 2017 are taken and a cubic spline is constructed through these. 503 equidistant points on the spline together with the start and end point of the original observations give the new data points. Compared to the original monthly time series the generated pseudo data turn out to always closely fit to its neighboring actual data points. In Al Awad and Goodwin (1998) a similar interpolation with cubic splines is performed in order to obtain weekly consumer price indexes. They state, that the index is rather non-noisy and therefore the interpolation fits well.

The observations are now further processed in order to access them appropriately for the research. For simplicity, in the following the US is called 'home' country, while any of the other countries is named 'foreign' country.

The interest rates in the time series are given as annual rate. The monthly interest rate differential $i_t - i_t^*$ at time t between the US and the foreign country is converted from annual data to the effective periodic rate by using the formula

$$i_t - i_t^* = 100 * [(1 + \frac{y_t}{100})^{\frac{1}{12}} - (1 + \frac{y_t^*}{100})^{\frac{1}{12}}]. \quad (2.1)$$

y_t is the 1-month rate for interest on the US-Dollar and y_t^* the 1 month rate for interest on the foreign currency denominated as annual percentage value as it is given in the time series.

The exchange rates and consumer price indexes are both converted to logs and then multiplied with a factor of 100.

Thus, results in the research show percentage values.

2.2. Research in nominal Terms

In this section, in order to approach the interplay of exchange rates and interest rates, a first, simple assessment in nominal values is performed. In particular, the question addressed here is, if the well known uncovered interest parity puzzle can be observed for the BRICS countries. The results are compared to those of the G6 countries. First, however the equation for uncovered interest parity in logarithmic terms is derived. The research is performed with logs on one hand, because most of the literature does so and thus the results are more comparable and on the other hand because the log values allow for a more detailed linear regression analysis.

2.2.1. Interest Parity in Logarithms

In this subsection the derivation of interest parity in logarithmic terms is described. In particular, this is interesting in order to observe if there could be limitations of the time series analysis performed on emerging market economies as the BRICS countries are. Nominal interest rates often exceed that of western developed economies in absolute value and are more volatile as also the exchange rates to the US-Dollar are. Therefore, the logarithmization might yield less reliable outcomes of the empirical research.

Formally, let there be two countries A and B where A is the home country of an investor. Following the notation of Engel (2016), let S_t be the exchange rate at time t as price of country B's currency per one unit of the currency of home country A, i_t the interest in the home country A, and i_t^* the interest rate in the foreign country B for the time horizon from t to $t+1$, . Additionally, let K be money denoted in the home currency being invested in time t.

Thus, investing K in the home country A yields $(1+i_t)*K$ in period $t+1$.

	Home Country A	Foreign Country B
t	K	
	$\downarrow$	
$t+1$	$(1+i_t)*K$	

Investing the money in the foreign country B instead of home country A yields $S_t^{-1} * (1+i_t^*) * S_{t+1} * K$ in $t+1$.

	Home Country A		Foreign Country B
t	K	$\xrightarrow{S_t}$	$S_t^{-1} * K$ $\downarrow$
$t+1$	$S_t^{-1} * (1+i_t^*) * S_{t+1} * K$	$\xleftarrow{S_{t+1}}$	$S_t^{-1} * (1+i_t^*) * K$

Thus, the gain of a carry trade P_{t+1} paid off at time $t+1$ can be written as

$$P_{t+1} := (\frac{S_{t+1}}{S_t} * (1+i_t^*) - (1+i_t))$$

Uncovered Interest Parity as an ex ante condition now requires that this gain is expected to be zero given the information at time t. That is,

$$\mathbb{E}_t[P_{t+1}] = [\frac{\mathbb{E}_t[S_{t+1}]}{S_t} * (1+i_t^*) - (1+i_t)] \stackrel{!}{=} 0, \tag{2.2}$$

where $\mathbb{E}_t$ denotes the conditional expected value at time t.

For shorter time periods and country pairs which do not show a huge volatility, i.e. sudden jumps, in their spot rate it can be assumed that $\frac{S_{t+1}}{S_t} \approxeq 1$.

Further also for interest rates of countries which do not show characteristics of strong inflation, it can be assumed that $1+i_t^*$ is close to unity for shorter periods of time (e.g. one month).

Thus, by using a first-order log approximation with s_t denoting $\ln(S_t)$

$$\begin{aligned}
\underbrace{\frac{\mathbb{E}_t[S_{t+1}]}{S_t} * (1+i_t^*)}_{\approxeq 1} - (1+i_t) &\approxeq \ln(\mathbb{E}_t[S_{t+1}] - S_t + 1 + i_t^*) + 1 - (1+i_t) \\
&\approxeq \mathbb{E}_t[s_{t+1}] - s_t + ln(1+i_t^*) - i_t \\
&\approxeq \mathbb{E}_t[s_{t+1}] - s_t + i_t^* - i_t
\end{aligned}$$

However, it is necessary to state that for simplification additionally $\mathbb{E}[s_{t+1}] \approxeq ln(\mathbb{E}[S_{t+1}])$ was used here, which does not necessarily hold and is depending on the underlying distribution of the exchange rate. Engel (2016) states, that if the exchange rate was conditionally log normal distributed then $\ln(\mathbb{E}_t[S_{t+1}]) = \mathbb{E}_t[s_{t+1}] + \frac{1}{2}\mathbb{V}_t[s_{t+1}]$. Given the exchange rate actually was approximately distributed conditionally log normal, aboves condition to restrict research on country pairs and interest rates over time intervals not showing a large volatility of the exchange rate can be applied once more.

Finally, the ex post return ρ_t of an uncovered carry trade can be written as

$$\rho_t := s_{t+1} - s_t + i_t^* - i_t$$

as it is also defined in Engel (2016)

This allows for reformulating the uncovered interest parity hypothesis in equation (2.2), which is subject matter of the following research as

$$\mathbb{E}_t[\rho_{t+1}] := \mathbb{E}_t[s_{t+1}] - s_t + i_t^* - i_t \stackrel{!}{=} 0$$

2.2.2. Empirical Results for nominal Interest Parity

In this chapter the results of an empirical analysis of a regression on nominal values is described. The data are taken from datastream and contain monthly values of nominal interest rates from the countries Brazil, Russia, India, China, and South Africa (BRICS countries) as well as the US and monthly exchange rates of the BRICS countries currencies to the US-Dollar from October 2007 until April 2017.

A simple regression on nominal interest rates and log exchange rates is performed analogously as in Engel (2016). In particular, the question addressed her is, if there is some pattern for gains of uncovered carry trades from the US to another country, with respect to the interest rate differential.

Let i_t be the interest rate of the US, i_t^* the interest rate of the foreign country, and s_t the log exchange rate between the two countries (as foreign currency per US-Dollar). Thus, the regression performed is written as

$$s_{t+1} - s_t + i_t^* - i_t = \alpha + \beta * (i_t^* - i_t) + \epsilon_{t+1}, \tag{2.3}$$

where ϵ_t describes the error term.

If the exchange rate would react on the interest rate differential in the way that interest parity suggests, the intercept α and the slope β were both zero. However, a lot of empirical research has shown that β is often positive, that is, there is a positive correlation of the interest rate differential to the carry trade gain.

The results for the BRICS-countries are listed in table 2.1.

Table 2.1.: Fama regression (2.3) in nominal terms - BRICS

	Intercept	**90% c.i. Int.**	**Slope**	**90% c.i. Slope**	**R^2**
Brazil	0.500	(-0.908,1.909)	1.0480	(-0.873,2.97)	0.005
Russia	-0.106	(-1.724,1.512)	2.3980	(-1.223,6.021)	0.021
India	-1.010	(-2.576,0.555)	3.5120	(0.651,6.374)	0.042
China	-0.119	(-0.266,0.027)	1.3070	(1.004,1.611)	0.401
South Africa	3.529	(-0.729,7.788)	-4.5810	(-13.151,3.989)	0.011

The confidence intervals are constructed with Newey-West standard errors. It is evident that the 90% confidence interval of the intercept includes the zero for all the BRICS countries. In the case of Brazil, Russia, India, and China the slope is positive. For the latter two the 90% confidence interval also excludes the zero. Only for South Africa the slope is negative while this is not significant at the 90% confidence level. An interesting result is the high R^2 value for China of about 40%. This can be explained by the fact that the exchange rate of the Renminbi to the US-Dollar only shows small volatility and a gradual appreciation. Thus, the negative but small intercept (in absolute value), and the slope being slightly bigger than 1 is likely to derive from the interest rate differential being perfectly correlated to itself.

Table 2.2.: Fama regression (2.3) in nominal terms - G6

	Intercept	**90% c.i. Int.**	**Slope**	**90% c.i. Slope**	$\mathbf{R^2}$
Canada	0.439	(-0.61,1.489)	-2.8130	(-21.564,15.937)	0.002
France	-0.231	(-0.629,0.165)	-1.2620	(-7.094,4.569)	0.001
Germany	-0.231	(-0.629,0.165)	-1.2620	(-7.094,4.569)	0.001
Italy	-0.231	(-0.629,0.165)	-1.2620	(-7.094,4.569)	0.001
Japan	0.383	(-0.075,0.842)	10.0730	(4.077,16.07)	0.08
UK	-0.071	(-0.604,0.462)	-8.3970	(-19.763,2.969)	0.047

Results for the G7 countries using Eurocurrency deposits for monthly interest rates are listed in table 2.2. These results are in particular interesting as they can be compared to those of Engel (2016). By using Eurocurrency deposits as interest rates the data for France, Germany, and Italy are the same, because the timeseries for the individual countries interest rates coincide since the introduction of the euro. It can be observed that the 90% confidence interval for the intercept includes the zero in all of the G6 countries, just like in Engel (2016). The slope coefficient, however, is negative for Canada, the Eurozone countries, and the UK and the 90% confidence interval is clearly excluding the zero in these cases. Only Japan shows a significantly positive slope. It is very likely that this results are biased by the underlying period of time. Since the time series are starting in 2007 they are strongly influenced by the latest financial crisis and might therefore produce different outcomes, as Engels research spreads over 30 years (ending in 2009, just partially covering periods of the financial crisis since 2007). Another article of Chaboud and Wright (2005) finds that uncovered interest parity does hold for a few hours but then there are already excess returns on uncovered carry trades over the period from 1988 to 1998 for a sample of developed countries.

In parts of the literature not the interest parity puzzle but the forward premium puzzle is investigated. Early papers investigating this, were Bilson (1980) and Fama (1984). The forward premium puzzle addresses the question if forward rates can predict future exchange rates. This puzzle is closely related to observing deviations from uncovered interest parity when taking covered interest parity into account as well. To show that, let f_t be the forward rate of the currency in $t+1$ offered at time t. The regression on the forward premium puzzle is often formulated as

$$s_{t+1} - s_t = \alpha + \hat{\beta}(f_t - s_t) + u_t \tag{2.4}$$

under the hypothesis that α is 0 and $\hat{\beta}$ is 1. However, it often reveals a negative correlation between exchange rate depreciation and forward premium, in particular between developed economies (see e.g. Bansal and Dahlquist (2000)).

If covered interest parity holds, it is

$$f_t - s_t + i_t^* - i_t = 0$$

This, in fact is close to being a no-arbitrage condition and there is plenty of evidence that deviations from covered interest parity are not very strong and are often rationalized with transaction costs (see e.g. Bhar, Kim, and Pham (2004)). The article of Taylor (1987) finds clear evidence for covered interest parity for short term horizons. A more recent paper of Skinner and Mason (2011) studies covered interest parity for a group of developed and emerging economies. The findings are that for developed countries the hypothesis is well confirmed but for a couple of emerging countries including Brazil and Russia while being confirmed for a 3 month-maturity it is not for 5 years and deviations can be explained by credit risk rather than transaction costs. Under the assumption that covered interest parity over a month holds, the forward premium can be rewritten as

$$f_t - s_t = i_t - i_t^*$$

Reformulating the forward premium regression in (2.4) yields the regression (2.3) of the interest parity with $\beta = 1 - \hat{\beta}$. This helps to compare the results of the research in this thesis with more literature, e.g. Bansal and Dahlquist (2000). The only countries observed in this thesis which significantly show the classical pattern of the uncovered interest parity puzzle or forward premium puzzle in nominal terms are in fact Japan, India, and China. Nevertheless, it should be noticed that for the BRICS countries there is evidence that covered interest parity is violated as it is presented in Bhargava, Dania, and Malhotra (2011) for Brazil, Russia, India, and China (BRIC) but this might not imply arbitrage due to transaction costs or constraints on trading.

2.3. Empirical Research in real Terms

In this section, the question addressed is, in how far the Interest Parity Puzzle for the BRICS countries can be observed in real terms. Furthermore, it is also assessed, how current real exchange rates are effected by expectations on the real exchange rate for the next month. Finally, it is investigated, if the effect of a shock on real interest rates can account for a persistent effect on the real exchange rate. As Engel (2016) points out, investigating interest parity in real terms is particularly interesting because theory often has assumptions on the interplay of exchange rates and interest rates in real rather than nominal values.

2.3.1. A Vector Error Correction Model

In this subsection a central building block of the analysis in real terms is described. In order to be able to ex-ante estimate real interest rates and exchange rates, a reasonable model is needed to forecast these variables. The empirical research in this thesis follows the method described in Engel (2016) including a Vector Error Correction Model for these forecasts. There is a small deviation in the way of forecasting though, due to the fact that the data in this thesis contains overlapping data. By using weekly data for 1-month interest rates, the holding periods overlap 4-5 consecutive weekly observations. The usage of overlapping data within the topic of interest rates and exchange rates has already been applied in the early paper of Hansen and Hodrick (1980) in a research on nominal values.

The data for the interest rates and the exchange rates are taken from Datastream and derive from the same time series as those in the chapter about nominal terms. Differently though, the data are now observed weekly and range until the 29th of May 2017. Still, the research focuses on monthly holding periods for the interest bearing assets and thus, these periods are overlapping. The problem of serial autocorrelation is overcome with a Vector Error Correction Model with three Lags (i.e., covering the data of the last four weeks) and using heteroskedasticity and autocorrelation consistent

Newey-West standard errors as it is also performed in Zacharatos and Sutcliffe (2002). But the Vector Error Correction Model of course is not applied for a mere technical reason. As Engel (2016) points out, the model includes effects of short term dynamics into the research. In a crisis-driven environment as it is researched here, the important dynamics might derive from an even narrower time frame of about one month instead of three months (as in Engel (2016)). Furthermore, the Vector Error Correction Model yields the advantage that it can adjust the variables for possible cointegration in the time series.

In table A.1 of the Appendix the results of an Augmented Dickey Fuller Test with seven lags are presented. The hypothesis that the nominal interest rate differential has a unit root can clearly be rejected at a 95% confidence level for all countries but Canada, the UK, and South Africa. Interesting though, the latter two show very high p-values of more than 50%. Still, given that a majority of the countries do not show any sign of a unit root, the decision is made that the nominal interest rate differential is not taken into account for possible cointegrating relationships.
Differently, for most countries a unit root of the consumer price differential cannot be rejected, though the Augmented Dickey Fuller test also reveals, that a Unit Root of the consumer price differential can be clearly rejected at 99% confidence for China, France, and Germany. It is important to mention here, that the results for the consumer price differential might be biased because of the construction of the weekly data with a cubic spline.
Finally, for the nominal exchange rate a unit root cannot be rejected for all countries at a satisfying confidence level. Moreover, with close to 95% confidence the exchange rate of the Renminbi shows strong evidence of a unit root, which might be explained by the gradual adjustion of the exchange rate to the US-Dollar. Summarizing this results, there might be possibilites of cointegration between the consumer price differential and the nominal exchange rate in some countries in the sample, which is Brazil, Russia, India, South Africa, Canada, Japan and the UK by applying the rule, that the hypothesis of a unit root is not rejected in both series at more than 30% confidence.

In the next step a Johansen Test according to the method of Johansen (1991) is performed in order to further investigate, if there is cointegration between consumer price differential and nominal exchange rate in some countries.

The results of the test are presented in the Appendix in table A.2 and show, that a cointegrating relationship can be rejected at a 90% confidence level for Russia, China, France, and Germany only. Given this evidence, that for the other seven countries in the sample cointegration cannot be excluded with certainty, the choice for a Vector Error Correction Model instead of a simple Vector Autoregression Model is made.

Let s_t denote the nominal log exchange rate at time t, p_t the log consumer price level at time t, and i_t the nominal log interest rate over the next month given at time t. A star denotes that the variabe is denoted in the foreign country. The price level in this context is used as measure for inflation. The Vector Error Correction Model is build up in the following way:

$$\begin{aligned} X_t - X_{t-1} &= C_0 + G * X_{t-1} + C_1 * (X_{t-1} - X_{t-2}) \\ &\quad + C_2 * (X_{t-2} - X_{t-3}) + C_3 * (X_{t-3} - X_{t-4}) \\ &\quad + u_t, \end{aligned} \tag{2.5}$$

where

$$X_t = \begin{pmatrix} s_t \\ p_t - p_t^* \\ i_t - i_t^* \end{pmatrix}, G = \begin{pmatrix} g_{11} & -g_{11} & g_{13} \\ g_{21} & -g_{21} & g_{23} \\ g_{31} & -g_{31} & g_{33} \end{pmatrix} \in \mathbb{R}^{3x3},$$

and $C_0 \in \mathbb{R}^3, C_1, C_2, C_3 \in \mathbb{R}^{3x3}$ are unrestricted

So $i_t - i_t^*$ denotes the nominal interest rate differential between the US and the foreign country, while $p_t - p_t^*$ is the price differential, both at time t. In more detail, it is

$$
\begin{aligned}
G * X_{t-1} &= \begin{pmatrix} g_{11} & -g_{11} & g_{13} \\ g_{21} & -g_{21} & g_{23} \\ g_{31} & -g_{31} & g_{33} \end{pmatrix} * \begin{pmatrix} s_{t-1} \\ p_{t-1} - p^*_{t-1} \\ i_{t-1} - i^*_{t-1} \end{pmatrix} \\
&= \begin{pmatrix} g_{11}[s_{t-1} - (p_{t-1} - p^*_{t-1})] + g_{13}(i_{t-1} - i^*_{t-1}) \\ g_{21}[s_{t-1} - (p_{t-1} - p^*_{t-1})] + g_{23}(i_{t-1} - i^*_{t-1}) \\ g_{31}[s_{t-1} - (p_{t-1} - p^*_{t-1})] + g_{33}(i_{t-1} - i^*_{t-1}) \end{pmatrix} \\
&= \begin{pmatrix} g_{11}q_{t-1} + g_{13}(i_{t-1} - i^*_{t-1}) \\ g_{21}q_{t-1} + g_{23}(i_{t-1} - i^*_{t-1}) \\ g_{31}q_{t-1} + g_{33}(i_{t-1} - i^*_{t-1}) \end{pmatrix},
\end{aligned}
$$

where $q_t := s_t + (p^*_t - p_t)$ denotes the log real exchange rate expressed as value of the foreign currency per US Dollar at time t.
Including this vector of $G * X_{t-1}$ in the model now enables to adjust for possible cointegration between the nominal exchange rate and the price differential.

The results for g_{11}, g_{12} and $g_{11} - g_{21}$ are shown in the Appendix in table A.3, A.4, and A.5. It can be seen, that for most countries the coefficient estimate is clearly not smaller than 10% of the coefficients which were estimated by the bootstrap. Still, for France, and Germany the cointegrating relationship is significant at a 10% level, and for Italy is very close to the 10% as well.

The main finding of this analysis is, that there is no clear evidence of mean reversion in the real exchange rate. This is contrary to many observations in the literature, e.g. in Jorion and Sweeney (1996) or Engel (2016). The different outcome might derive from the different time periods which are observed. Often mean reversion of the real exchange rate is investigated over decades of the post Bretton-Woods era and not with data covering less than 10 years. The recent article of Kutan and Zhou (2015) finds that for many countries stationarity of the real exchange rate is evident over the post Bretton-Woods era but often the mean reversion is non-linear. Given non-linear mean reversion was present in the sample of this thesis, the Vector Error Correction Model could not reflect this appropriately. The research now proceeds under the assumption that purchasing power parity between countries does hold in the long run but it should be noticed that the data observed give evidence that this might not always be the case and interpretations which make use of the assumption of mean reversion in the real exchange rate should be evaluated carefully.

As an extension of the Vector Error Correction Model, as also Engel (2016) is mentioning, other dependent variables like gold or oil price in dollars could be included in the model. While Engel (2016) does not observe a different pattern for the G6-countries by including other independent variables in his sample, it is of interest if including prices of raw materials would yield stronger results, at least for some of the BRICS-countries. The price of raw materials certainly contains expectations which are forward-looking and the dollar exchange rates of the BRICS-countries might depend highly on the price of the most important raw materials for the respective country because the importance of some raw materials in the domestic economy as well as in international trade might be large.

2.3.2. Interest Parity in real terms

Extending the empirical research on real values, the estimates from the Vector Error Correction Model are first used, to repeat the Fama-regression which was already performed on nominal values. Therefore, estimates of the real interest rate need to be constructed. As for an investor ex-ante the real interest rate for the next month is unknown, it is approximated by expectations on the relative inflation level for the following month. This expectations will be estimated via the Vector Error Correction Model described in the previous chapter. The analysis still deals with weekly observations such that for simplicity it is assumed that four weeks are approximately one month and the consumer prices do not change a lot in the one to three days that are not covered. This time, the relation between gains of carry trade in real terms are explained by the real interest rate differential between two countries. The regression is formulated as

$$q_{t+4} + \hat{r}_t^* + q_t - \hat{r}_t = \alpha + \beta * (\hat{r}_t^* - \hat{r}_t) + u_t \tag{2.6}$$

The estimator $\hat{r}_t^* - \hat{r}_t$ for the real interest rate differential of the next month (i.e. 4 weeks, from t to $t+4$) is constructed as

$$\hat{r}_t^* - \hat{r}_t = (i_t^* - i_t) + (\hat{\mathbb{E}}_t[(p_{t+4}^* - p_t^*) - (p_{t+4} - p_t)]),$$

where $\hat{\mathbb{E}}_t$ denotes an estimator for the conditional expected value at time t. This estimator of the relative inflation rate $(p_{t+4}^* - p_t^*) - (p_{t+4} - p_t)$ over one month (i.e. 4 weeks) needs to be constructed first. For this purpose, the Vector Error Correction Model is applied, such that the relative inflation rate is forecasted by the behavior of previous observations.
It holds, that

$$(p_{t+4}^* - p_t^*) - (p_{t+4} - p_t) = (p_{t+4}^* - p_{t+4}) - (p_t^* - p_t)$$

For simplicity, let $\pi_t = (p_t^* - p_t)$ denote the consumer price index differential at time t. Rewriting the relative inflation rate by a telescoping sum yields

$$\pi_{t+4} - \pi_t = \sum_{i=1}^{4} (\pi_{t+i} - \pi_{t+i-1}).$$

The single parts of the sum on the right side of the equation are now estimated one after another. First, $\hat{\mathbb{E}}_t[\pi_{t+1} - \pi_t]$, $\hat{\mathbb{E}}_t[q_{t+1}]$, and $\hat{\mathbb{E}}_t[i_{t+1} - i_{t+1}^*]$ are estimated by the coefficients of the restricted Vector Autoregressive Model

$$X_t = C_0 + C_1 * X_{t-1} + C_2 * X_{t-2} + C_3 * X_{t-3} + C_4 * X_{t-4} + u_t, \tag{2.7}$$

where

$$X_t = \begin{pmatrix} q_t \\ \pi_t - \pi_{t-1} \\ i_t - i_t^* \end{pmatrix}, C_4 = \begin{pmatrix} c_{11} & 0 & c_{13} \\ c_{21} & 0 & c_{23} \\ c_{31} & 0 & c_{33} \end{pmatrix}$$

Note, that this restricted Vector Auto Regression is in fact just another representation of the vector error correction model (2.5) presented in the previous subsection. Thus, the coefficients of the Vector Error Correction Model can also be obtained by a linear transformation of this restricted vector autoregressive model.

Then the estimates replaces the real life observation at time $t+1$ as pseudo data. Next, the 3 variables are estimated for $t+2$ in the same way, but already making use of the pseudo observations at time $t+1$ resulting in another newly constructed data point for $t+2$. Repeating this procedure for $t+3$ and after that for $t+4$ now enables to construct an expectation of the relative inflation rate over the following 4 weeks. Applying linearity of the expected value, an estimation of $\pi_{t+4} - \pi_t$ at time t is constructed by

$$\hat{\mathbb{E}}_t[\pi_{t+4} - \pi_t] = \sum_{i=1}^{4} \hat{\mathbb{E}}_t[(\pi_{t+i} - \pi_{t+i-1})]. \tag{2.8}$$

The construction of this estimator is certainly not the most sophisticated method of forecasting. First of all, it should be noticed that the 'true' values of inflation are already constructed values by a cubic spline interpolation and thus are estimates themselves. Further, the accuracy of the forecast is highly depending on the ability of the Vector Error Correction Model to already forecast the first differences very well. Each time the error of the estimate of the Vector Error Correction Model enters the next step of the estimating procedure. In the Appendix in table A.6 and A.7 the mean squared error and bias of the estimate is reported for each country.
In comparison to this, in Engel (2016) the relative inflation rate is directly estimated by the Vector Error Correction Model because he is not using overlapping data. Still, he also points out that agents are likely to rely on better forecasting techniques by including more information.

The results of regression (2.6) for the G6 countries are listed in Table 2.3. Below the coefficients for each country the Newey-West standard error is reported in brackets. With the help of two different bootstraps 90% and 95% confidence intervals are generated and reported in brackets next to the coefficient as well. The upper bootstrap is a percentile, the lower a percentile-t bootstrap and are reported in the appendix for Engel (2016).
The results are very interesting. The intercept is close to zero for all G6

Table 2.3.: Fama Regression (2.6) in real Terms - G6

	Intercept	90% c.i. Intercept	95% c.i. Intercept
Canada	0.465 (0.257)	(0.485,1.061) (0.486,1.107)	(0.427,1.106) (0.425,1.17)
France	0.333 (0.292)	(0.201,0.838) (0.198,0.872)	(0.13,0.892) (0.127,0.922)
Germany	0.283 (0.285)	(0.164,0.892) (0.176,0.884)	(0.092,0.965) (0.102,0.982)
Italy	0.300 (0.256)	(0.17,0.784) (0.176,0.777)	(0.09,0.863) (0.117,0.837)
Japan	-0.069 (0.355)	(-0.496,0.091) (-0.589,0.118)	(-0.536,0.133) (-0.646,0.184)
UK	0.393 (0.311)	(0.601,1.038) (0.617,1.125)	(0.573,1.081) (0.581,1.183)
	Slope	**90% c.i. Slope**	**95% c.i. Slope**
Canada	-3.3280 (1.331)	(-4.686,-1.881) (-5.641,-0.982)	(-4.95,-1.608) (-6.203,-0.581)
France	-2.2590 (0.748)	(-3.237,-1.036) (-3.416,-0.918)	(-3.41,-0.842) (-3.613,-0.627)
Germany	-1.7430 (0.654)	(-2.663,-0.648) (-2.718,-0.61)	(-2.884,-0.351) (-2.95,-0.35)
Italy	-3.0880 (0.803)	(-4.277,-1.728) (-4.41,-1.679)	(-4.545,-1.487) (-4.629,-1.369)
Japan	0.3150 (0.766)	(-0.688,1.519) (-0.792,1.76)	(-0.905,1.777) (-1.009,2.116)
UK	-1.0600 (1.204)	(-2.001,0.028) (-2.982,1.047)	(-2.196,0.16) (-3.427,1.456)

countries but significantly positive for all cases but Japan. In all cases, leaving out Japan, the zero is not included in the 95% interval.
The slopes for the G6 countries omitting Japan show another clear common pattern. For all this countries the slope is clearly negative. The UK is the only of this countries which is not significant at 90%, but in the first bootstrap it is very close to. Thus, the interest parity puzzle in real terms seems to be reversed for the G6 countries with the exception of Japan.

Chang and Su (2015) find that for short term investments real interest parity holds for the G6 countries for the period from 1977 till 2005 using quarterly data. The contrary findings of them with regards to Engel (2016) who reports a positive correlation between ex ante excess returns and expected interest rate differential could be explained by the different holding periods as well as the different method of estimating real interest rates.

Table 2.4 reports results from the same analysis for the BRICS countries. The intercept is positive for all countries. But while for China it is very small and both confidence intervals include the zero, the other countries show a coefficient of about 1 for the case of India up to around 2 for Brazil. These four countries' 95% confidence intervals also clearly exclude the zero.
The slope is significantly negative for Brazil and South Africa at a 95% confidence interval. For Russia and India the slope is negative but not significant.
An interesting outlier in this sample is China. Showing a slope of 0.538 which is significantly positive and the intercept of 0.035 being very close to zero, China also shows in real terms, that the expectations of gains in carry trades strongly derive from the expected interest rate differential, confirming the observations of the previous analysis in nominal terms. The reason for that is most likely a strong influence of the policymaker on the exchange rate. The result which can be observed here is certainly deriving from a rather small volatility of the real exchange rate of the Renminbi to the US-Dollar.
The main finding for most of the countries is, that the relation between appreciation of the currencies and expected real interest rate differential is negative. The significantly positive intercept however, reflects the fact that there needs to be other important factors that drive the appreciation of currencies in real terms in the opposite way. The findings presented here coincide with those of Bansal and Dahlquist (2000) who have observed that

Table 2.4.: Fama Regression (2.6) in real Terms - BRICS

	Intercept	90% c.i.	95% c.i.
Brazil	2.069	(1.328,3.026)	(1.109,3.2)
	(0.675)	(1.223,3.301)	(1.025,3.488)
Russia	1.417	(1.284,3.223)	(1.126,3.369)
	(0.72)	(1.28,3.561)	(1.104,3.814)
India	0.969	(1.043,1.72)	(0.978,1.81)
	(0.345)	(1.044,1.895)	(0.977,1.961)
China	0.035	(-0.152,0.154)	(-0.183,0.181)
	(0.14)	(-0.186,0.176)	(-0.227,0.216)
S. Africa	1.860	(1.783,2.863)	(1.691,2.954)
	(0.543)	(1.761,3.295)	(1.613,3.455)
	Slope	**90% c.i.**	**95% c.i.**
Brazil	-2.508	(-3.541,-1.042)	(-3.692,-0.842)
	(0.936)	(-3.914,-0.43)	(-4.178,-0.12)
Russia	-0.644	(-1.611,0.786)	(-1.784,0.981)
	(1.43)	(-3.008,2.686)	(-3.546,3.262)
India	-0.219	(-0.684,0.166)	(-0.75,0.25)
	(0.26)	(-0.709,0.164)	(-0.826,0.254)
China	0.538	(0.432,0.917)	(0.397,0.95)
	(0.121)	(0.442,0.927)	(0.415,0.974)
S. Africa	-4.011	(-5.241,-2.293)	(-5.557,-2.044)
	(1.498)	(-6.117,-1.107)	(-6.544,-0.544)

ex ante excess returns are particularly evident, when interest rates in the US exceeds that of the BRICS-countries. In Bahmani-Oskooee et al. (2016) there is an analysis of this relationship as well for the BRICS countries over the years 1996 to 2015. Their findings are different and show that real interest parity is a reasonable assumption.

2.3.3. The direct Impact of expected Inflation on the current Exchange Rate

In the following, the behavior of the current real exchange rate with regards to the expected real interest rate differential over the next 4 months is observed. This is interesting because investors might directly act on news regarding expected inflation and interest rates and thus, inflict a direct impact on the interest rate. In order to observe this, the regression

$$q_t = \alpha + \beta * (\hat{r}_t^* - \hat{r}_t) + u_t \tag{2.9}$$

is performed. Results from this regression for the G6 countries are reported in Table 2.5

The results show a different picture than those of Engel (2016). All coefficients with the exception of the UK are clearly negative. For Japan this is also significant at a 95% Level. In Engel (2016) the coefficients are positive for all countries and significantly at more than 90% with the first bootstrap method. The different outcomes in the research might derive either from the different method of estimating the relative inflation rate or from the data.
The clear reversal of the results is more likely to be borne out of the data then of the slightly adapted way of estimating the relative inflation rate or the Vector Error Correction Model which only accounts for data of the last 4 weeks instead of the last 4 months. The crisis and post-crisis era from 2007 to 2017 out of which the observations in this thesis are taken is likely to bear a different behavior of the economic variables of interest rates, exchange rates and inflation compared to a sample from 1973 to 2009.
A further explanation deriving from the observations might be the different

Table 2.5.: Regression (2.9) of current exchange rate on expected real interest rate differential - G6

	Slope	95% conf. Interval	90% conf. Interval
Canada	-3.429	(-12.404,3.718)	(-13.634,6.993)
	(3.763)	(-15.288,1.135)	(-17.854,2.793)
France	-1.473	(-7.206,3.891)	(-8.129,5.608)
	(3.914)	(-12.006,4.037)	(-14.055,6.205)
Germany	-2.498	(-7.999,3.567)	(-8.656,5.211)
	(3.384)	(-11.715,3.168)	(-13.053,4.509)
Italy	-1.228	(-8.419,5.417)	(-9.336,7.071)
	(5.442)	(-12.383,5.66)	(-14.457,7.813)
Japan	-7.237	(-19.181,-2.651)	(-20.909,-0.228)
	(4.334)	(-23.387,-3.228)	(-26.487,-1.361)
UK	0.011	(-5.848,3.318)	(-6.756,4.411)
	(5.136)	(-13.695,6.716)	(-16.284,8.629)

approach of observing weekly instead of monthly data. Both methods might yield there own bias and thus, produce different outcomes. As an example, there might be a preference for investors to rather trade on specific days in the week than at others. On the other hand, there might be a bias for monthly observations, when agents prefer to trade (or not to trade) at the end of the month rather than at some other day. In particular, both biases in behavior would result in an increased or decreased demand of the foreign currency and thus, determining the price as well as expectations on future spot rates as well as the liquidity of the currency at these dates. A possible weekday bias of the Forex market is described in McFarland, Pettit, and Sung (1982). In a more recent paper of Paukštė and Raudys (2013) evidence is presented that the weekday does have an impact on liquidity while the day of the month does not. As the observations used in this thesis were all taken on Mondays this might account for the results.

In Table 2.6 the regression of (2.9) is shown for the BRICS-countries.

The results for the BRICS countries show a very different picture. The slope

Table 2.6.: Regression (2.9) of current exchange rate on expected real interest rate differential - BRICS

	Slope	95% conf. Interval	90% conf. Interval
Brazil	11.892 (11.396)	(-3.472,27.868) (-13.735,46.309)	(0.539,25.575) (-7.494,42.287)
Russia	15.666 (10.002)	(1.541,32.714) (-3.717,58.208)	(6.343,30.604) (0.562,49.752)
India	7.786 (4.4)	(9.317,18.041) (9.443,42.706)	(10.113,17.166) (10.399,37.678)
China	-0.577 (1.985)	(-3.102,0.671) (-10.24,2.66)	(-2.87,0.292) (-8.624,1.523)
S. Africa	-1.232 (16.605)	(-15.635,8.596) (-30.076,15.882)	(-13.167,6.366) (-26.12,11.795)

is reported negative only for China and South Africa, but not significant in both cases. China, though is nearly significant at a 90% level. The absolute value of the slope as well as the range of the confidence intervals is much smaller for China than for all other countries. This again indicates that the Renminbi just lacks the volatility of the other currencies. The slopes of Brazil, Russia and India are highly positive and significantly exclude the zero for the latter two at a confidence level of 95% with the first bootstrap method. Brazil is significantly positve at 90% with the same bootstrap. That is, there is a common pattern for the Brazilian Real, the Russian Rouble, and the Indian Rupee to directly appreciate in real terms, if the real interest rate differential to the USA is expected to be positive. Compared to the results of regression (2.6) it seems like there is an excess instant reaction of the exchange rate differential on expected inflation which is not canceled out by some sort of interest parity over the next month. This behavior of an instant reaction on the real exchange rate is assumed in many early economic models, e.g. the model of Dornbusch (1976). Interpreting the results of the regression coefficient in actual numbers this means, that when the interest rate of Brazil exceeds that of the USA in 1% in annual terms, the Brazilian Real is expected to directly appreciate by about 0.99% (that is $\frac{1}{12}$-times the coefficient), the Russian Rouble by about 1.31% and the Indian Rupee by about 0.65%. Nevertheless, the huge confidence intervals state that these interpretations in absolute values should be performed with care.

2.3.4. Future expectations on exchange rates and interest rates

The next interesting topic to observe is, how an expected interest rate differential does affect the real exchange rate in the longer run. Following the approach in Engel (2016), a Beveridge-Nelson decomposition of the exchange rate can be performed. Assume the holding period of the interest bearing asset now just spreads over two consecutive observations. By taking telescoping sums, the expected value for the nominal exchange rate s_{t+k} at time t can be expressed as

$$\mathbb{E}_t[s_{t+k}] = s_t + \sum_{k=0}^{\infty} \mathbb{E}_t[s_{t+k+1} - s_{t+k}] \tag{2.10}$$

$$= s_t + \sum_{k=0}^{\infty} (\mathbb{E}_t[\rho_{t+k} - (i^*_{t+k} - i_{t+k})] \tag{2.11}$$

.

That means, the non-stationary nominal exchange rate can be rewritten by a forecast on itself and two stationary series of the expected interest differential and expected ex ante excess returns. This allows for applying the decomposition of Beveridge and Nelson (1981). Applying the forecast for an infinitely far away time point k and subtracting (unconditional) long term means yields

$$\begin{aligned} s_t &= \lim_{k\to\infty} [\mathbb{E}_t[s_{t+k}] - k(\overline{s_{+1} - s})] \\ &- \mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+k+1} - \overline{\rho}] \\ &+ \mathbb{E}_t \sum_{k=0}^{\infty} [(i^*_{t+k} - i_{t+k}) - (\overline{i^* - i})] \end{aligned}$$

where a bar over a variable denotes its mean and $\overline{s_{+1} - s}$ is the mean of the change in the exchange rate over one period.

Thus, as the exchange rate was found to be non-stationary, s_t can be split into a transitory component s_t^T which consists of expected deviations in the interest rate differential and the sum of future ex ante returns as well as a permanent component $s_t^P = \lim_{k\to\infty} [\mathbb{E}_t[s_{t+k}] - k(\overline{s_{+1} - s})]$

In order to observe the transitory part of the exchange rate which derives from variations in the interest parity, equation (2.10) can be rewritten as

$$\begin{aligned}\mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+k+1} - \overline{\rho}] &= \lim_{k\to\infty} [\mathbb{E}_t[s_{t+k}] - k(\overline{s_{+1} - s})] - s_t \\ &+ \mathbb{E}_t \sum_{k=0}^{\infty} [(i^*_{t+k} - i_{t+k}) - (\overline{i^* - i})]\end{aligned}$$

This decomposition can be directly transformed into real values by adding respectively subtracting the price levels correctly. Under the assumption that the nominal exchange rate is stationary in first differences and that there is mean reversion in the real interest rate in the long run, aboves Beveridge-Nelson decomposition thus translates to

$$\begin{aligned}q_t - \overline{q} &= \mathbb{E}_t \sum_{k=0}^{\infty} [(r^*_{t+k} - r_{t+k}) - (\overline{r^* - r})] \\ &- \mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+k+1} - \overline{\rho}]\end{aligned}$$

as it is also described in Engel (2016).

Next, the regression

$$\mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+k+1} - \overline{\rho}] = \alpha + \beta * (\hat{r}^*_t - \hat{r}_t) + u_t, \tag{2.12}$$

is performed. The dependent variable in this regression is that part of the transitory component of the exchange rate which derives from deviations in interest parity. In fact, it is an estimated variable and what truely measured here is $\sum_{i=1}^{4} \mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+k+i} - \overline{\rho}]$. Note, that this is not exactly the form which was derived by the Beveridge-Nelson decomposition before because each carry trade overlaps three of its successors. The decomposition can be derived similarly for $\mathbb{E}_t \sum_{k=0}^{\infty} \rho_{t+4k+1}$ and taking differences over 4 lags for every fourth observation. Now the assumption is made that, based on the expectations at time t, $\mathbb{E}_t \sum_{k=0}^{\infty} \rho_{t+4k+1} \approxeq \mathbb{E}_t \sum_{k=0}^{\infty} \rho_{t+4k+1+i}$ for $i \in 1, 2, 3$ and thus, $\mathbb{E}_t \sum_{k=0}^{\infty} \rho_{t+k+1} \approxeq 4 * \mathbb{E}_t \sum_{k=0}^{\infty} \rho_{t+4k+1}$. Furthermore, for a computational penalty, the infinite holding period was cut down to 200 expected observations in the future. A dry run with 500 observations omitting the bootstraps was performed as well and showed similar results in the coefficients.

The results for the G6 countries are presented in Table (2.7)

Table 2.7.: Regression (2.12) of $\mathbb{E}_t \sum_{k=0}^{\infty} [\rho_{t+4k+1} - \overline{\rho}], k \in \{0, 4, ...\}$ on expected interest rate differential - G6

	Slope	95% conf. Interval	90% conf. Interval
Canada	-15.102	(-27.969,21.169)	(-24.94,14.46)
	(7.257)	(-37.596,14.432)	(-32.334,10.599)
France	-24.278	(-42.617,13.098)	(-39.547,8.1)
	(7.35)	(-65.267,21.763)	(-56.728,11.539)
Germany	-23.679	(-42.532,11.958)	(-39.772,6.832)
	(6.484)	(-62.159,7.617)	(-53.52,4.887)
Italy	-34.075	(-56.046,9.939)	(-52.815,2.115)
	(9.184)	(-69.982,11.888)	(-63.443,2.322)
Japan	-46.139	(-91.221,588.791)	(-77.926,502.019)
	(21.683)	(-139.363,690.975)	(-107.021,593.486)
UK	-12.765	(-23.836,56.621)	(-22.53,43.139)
	(7.016)	(-42.913,40.115)	(-35.814,33.073)

The slopes for all countries are negative but not significant at a 90% level.

Thus, an interpretation of the results should be performed very carefully. Only Italy is nearly significant at a 90% level.
The main focus of the research lies on the BRICS countries. The observations for these yield clearer results and are shown in Table 2.8.

Table 2.8.: Regression (2.12) of $\mathbb{E}_t \sum_{k=0}^{\infty}[\rho_{t+4k+1} - \overline{\rho}], k \in \{0, 4, ...\}$ on expected interest rate differential - BRICS

	Slope	95% conf. Interval	90% conf. Interval
Brazil	-66.586	(-131.832,18.136)	(-121.854,3.683)
	(17.861)	(-203.842,-4.283)	(-169.769,-13.669)
Russia	-193.943	(-249.431,0.997)	(-235.072,-32.168)
	(36.814)	(-273.976,82.194)	(-240.088,25.327)
India	-285.605	(-537.329,16.817)	(-514.076,-39.089)
	(37.333)	(-2158.396,149.848)	(-1453.02,101.756)
China	-281.701	(-457.233,-166.355)	(-443.448,-206.788)
	(8.953)	(-1091.847,-206.214)	(-913.652,-227.493)
S. Africa	-33.906	(-73.122,149.014)	(-67.234,127.301)
	(17.32)	(-138.445,232.664)	(-116.713,198.657)

The slope of all BRICS countries is reported negative and for each country but South Africa this finding is significant at 90% with at least one bootstrap method. In general, South Africa always follows the pattern of the G7 countries rather than coinciding with the BRIC countries in all the regressions which were run. In the case of China the real exchange rate of the dollar seems to rather follow a fixed pattern than expectations of traders on real interest rate differentials similar as it was already be observed in the previous regressions.

The results could now be interpreted following Engel (2016) under the assumption that the real exchange is mean reverting. That is, if the monthly real interest rate of one of these countries is expected to exceed that of the US by 1% in annual terms, then this has an effect of about $\frac{1}{52.2}$ times (an average year has about 52.2 weeks) the reported estimate on $\mathbb{E}_t \sum_{k=0}^{\infty}[\rho_{t+k+1} - \overline{\rho}]$. For e.g. the Brazilian Real, this means an impact of about 1.28%, for the Russian Rouble 3.72% and for the Indian Rupee the effect is 5,47%. Taking Brazil as example, and including the observations of Table 2.6 it could be interpreted that of the 0,99% the Real is directly appreciating by expectations on the subsequent interest rate differential, 1.28% are explained by expectations on future gains on carry trades. That is, the difference, which is expectations on future levels of interest rate differentials dampens the effect of appreciation of the real by 0.29%. Nevertheless, as the confidence intervals in both regressions are vast, these results in absolute numbers should be evaluated cautiosly. Also, because there is no clear evidence of mean reversion in the real exchange rate over the period observed, this implies that the last regression should be interpreted rather carefully. Future deviations from interest parity and interest rate differentials might not be the only factor for movements of the real exchange rate as there might be some long run drift which is not taken into account here.

As a conclusion to the empirical part in real terms it is important to once again mention that the outcomes of the analysis are highly depending on the strength of the underlying vector error correction model to estimate expectations on future exchange rates, interest rates and inflation very well. The very different individual outcomes of the analysis might strongly derive from the fact that the model is fitting well for some countries but not for others. Thus, a possible extension of the empirical analysis which was performed here could be to build individual models for each country in order to improve the strength of their estimation ability. Agents certainly do have much stronger and country-specific models on which they build their expectations and it is also very likely that these agents forecast inflation rates, interest rates and exchange rates of the BRICS countries by different factors and models than those for the G6 countries.

3. Liquidity Effects and the Real Exchange Rate

In this chapter the findings of the empirical analysis for the BRICS countries are discussed. First, the main findings are repeated and it is explained why classical explanations of the interest rate parity cannot account for these. Afterwards, spending attention on the market environment of the crisis and post-crisis era a setting is explained which can explain the findings by a strong effect of liquidity.

3.1. Heterogeneous Patterns in the Real Exchange Rate

The first finding shown in the empirical part of this thesis is that the expected gain of a carry trade over the next month is negatively correlated to the real interest differentials for all countries with a significant trend for all countries but China which shows a clear positive correlation and no trend. Furthermore, it was observed that real exchange rates of Brazil, Russia and India are directly overshooting on the expected interest rate differential to the US while China's and South Africa's currency are underreacting. Finally, evidence was presented that the correlation between real interest rate differential and the sum of average future ex ante excess returns is negative for all BRICS countries. This finding is similar to that of Engel (2016) for the G6 countries. Regarding the former results which already neglected the classical interest parity puzzle this does not yield so much controverse information as already the ex ante excess returns in the next period showed a negative correlation. However, this last result might be biased by an estimation error due to the statistical method applied and thus should be evaluated carefully.

To sum up, the findings for the different countries are heterogeneous and differ to results which are commonly observed in the literature and often show that either interest parity or the classical interest parity puzzle with its short-term underreaction of the exchange rate can be observed. For those currencies which show the pattern of overshooting of the exchange rate the model of Dornbusch (1976) seems to fit well. Nevertheless, this model neither takes into account country-specific circumstances nor specific effects of liquidity.

3.2. A model of liquidity premia

While theory has struggled with the findings that uncovered interest parity does not hold over shorter periods and thus yields excess returns and at the same time real interest rate show an excess overshooting on a longer time horizon, in Engel (2016) a model with rational behaviour is presented which can account for both findings.

The setting is based on the article of Nagel (2014), who has created a model in which liquidity preferences of investors for certain assets, such as time deposits demoninated in the home currency, play a role in determining an optimal consumption path. Engel (2016) extends this on a symmetric two-country setting and shows how a shock on liquidity changes the investment preferences of the households.

In order to reflect the situation which is observed in the empirical part, an investor in a country can decide to either hold money, short term deposits in the own currency, in this case the US dollar, or short term deposits in the foreign country. While money is considered to be fully liquid, the short term deposit abroad does not provide any liquidity for the investor. The short term deposit in the home currency, however, provides liquidity but less as money and as such it is called called near-money. The value of liquidity of this near-money is volatile and subject to shocks. Regarding these shocks the investor will adjust his portfolio due to his preferences for liquidity. When a negative shock hits the near money in terms of liquidity value, this leads to a decreased demand for short term deposits in the home country. This causes a decline in the value of the home currency as the investors are rebalancing their portfolios. At the same time the policymaker is intervening and adjusts inflation such that interest rates in the home country rise. That is, there are two shocks, one deriving from liquidity and one from the counteraction of the policymaker. The shock on liquidity induces a positive correlation of exchange rate differential and ex ante excess returns, the monetary shock a negative correlation. When the shock on liquidity is stronger in variance, it exceeds the monetary shock of the policymaker. But the monetary shock has a longer persistence and thus exceeds the shock on liquidity after some time. This can explain the findings of Engel (2016) very well who has found that the real interest rate differential is positively correlated to the next periods' ex ante return, but negatively with future returns.

3.3. Spillover effects of Quantitative Easing

In the following it is shown how a strong effect on liquidity can account for the findings regarding the BRICS countries. The findings for the G6 countries are not further taken into account

While the model of Engel (2016) describes a setting between two industrialized (and to some extent equally sized) economies well, it does not provide a proper explanation for the heterogeneous empirical results concerning the BRICS countries. A possible reason is that the reactions in the two-country setting might just not be symmetric for the US and an emerging country and also there are specific circumstances in the decade observed which have to be taken into account. These circumstances are likely to originate in the financial crisis which started in 2007. As it is reported in Fawley, Neely, et al. (2013) the FED then launched four consecutive programs of Quantitative Easing. In 2008 the first program (QE1) over a volume of $1725 billion. was announced. A second program (QE2) over $600 billon was announced in 2010 and provided the market with further liquidity. Then Operation Twist, announced in 2011 and extended in 2012, brought $667 billion (funded by selling shorter term securities) to the market and finally QE3 was launched in 2012 over $85 billion per month ending in 2014. In figure A.1 in the appendix the total assets held by the Fed from 2007 until 2017 are shown. It is evident, that the Fed holds more than 4 times more assets than before the beginning of the crisis, that is the monetary expansion in total was about $3.5 trillion.

Thus, for more than half of the time within the period of 2007 to 2017 there was a regime of quantitative easing in the US. It led to positive shocks on liquidity each month and stabilized the inflation rate in the US. But it also had a strong impact on the BRICS-countries. In Fratzscher, Lo Duca, and Straub (2016) the impact of Quantitative Easing in the US on other countries is investigated. The analysis provides insight that there were strong capital flows into emerging markets which derived from the monetary expansion in the US. In Lavigne, Sarker, Vasishtha, et al. (2014) possible spillover effects to emerging economies with flexible exchange rate regimes are discussed. Taking into consideration different spillover channels, it is explained, how quantitative easing may result in portfolio rebalancing of investors towards more risky assets in emerging markets, more persistence of interest rate differentials, a depreciation of the US dollar and negative consequences for exports from emerging markets to the US (which might be dampened by an increased demand in the US).

In the following a possible explanation is provided which shows how the effects of Quantitative Easing in the US might account for the findings of the empirical research with regards to the BRICS countries. Therefore the BRICS countries are divided in three different categories regarding the extent their respective central bank is intervening in the foreign exchange. Following Blanchard, Adler, and Carvalho Filho (2015) China's exchange rate policy is classified as *de-facto peg*, Brazil, Russia, and India are *interveners*, and South Africa is considered a *floater*. Though the countries in reality might act very different in terms of foreign exchange intervention, for simplification it is now assumed that each classification yields a somewhat stereotypical pattern of the policymaker.

First, consider a two country setting with the US being the home country and the foreign being one of either Brazil, Russia, or India, that is the *interveners*. The home country is the bigger economy in size and the foreign countries economy highly depends on exports to the home country. The home country runs a program of monetary expansion, the central bank is targeting inflation but domestic interest rates remain low. Now suppose, there is a state when real interest rates in the foreign country exceed that in the home country. That is, assets in the home country bear little interest in real terms, which might even be negative but there is plenty of liquidity in the domestic market due to quantitative easing. Thus, investors in the home country decide to invest in foreign assets which yield more interest and therefore expect higher returns. As there is huge demand for money in the foreign but little in the home country the foreign currency appreciates against the domestic. Thus, the monetary expansion in the home country has directly led to a positive liquidity shock in the foreign market. Due to the increased amount of money supply inflation would rise over the next periods in the foreign country but the policymaker there is still able to stabilize the prices. Meanwhile, the exchange rate appreciates over the time and the policymaker is starting to take counteractions and builds up reserves in the home currency in order to dampen the appreciation because the economy of the foreign country worries about its ability to export goods to the home country. The higher the real interest rate differential gets the stronger the policymaker counteracts such that finally the exchange rate drops so sharply that excess returns are negative now for an investor in the home country. Meanwhile, the policymaker cannot focus on targeting inflation so well. That is, the real exchange rate differential to the home country now drops over the next periods and the foreign currency depreciates now even more because investors learned that there is a risk on carry trades. Still, carry trades for investors of the home country become profitable again, while inflation in the foreign market grows. Finally, a state is reached where real interest rates of the home country exceed that of the domestic. However, in this state the policymaker in the foreign country is now concerned about liquidity in his economy because he expects strong capital flows to the home country. Thus, he decides to sell off the reserves of the foreign currency he was building up in the previous periods. In this time the ex ante excess returns are particularly high, as the real exchange rate differential is just slightly negative but the currency strongly appreciates over consecutive periods. At this point also inflation can be addressed efficiently by the policymaker of the foreign country and thus, real exchange rates again exceed that of the domestic country.

This setting might account well for the findings regarding Brazil, Russia, and India. Evidence for intervention of central banks to stabilize the exchange rate in the case of Brazil can be found in an newspaper article of Blackden (2012) in the Telegraph. For India intervention on the exchange rate is reported in Basu and Varoudakis (2013): "More recently, since August 2011, the RBI has intervened in FX markets in response to depreciation pressures, but has not attempted to change the direction of exchange rate movements. During the recent turmoil, from August 2011 to August 2012, the RBI conducted a combination of spot and forward FX market intervention"(p.15).

However, in the case of China the observations are different. The reason might be, that when the interest rate differential is expected to be high, the People's Bank of China directly reacts on appreciations of the renminbi by building up US dollar reserves and thus, depreciating its currency in real terms. In the case that the real interest rate differential is negative, the policymaker is again stabilizing the exchange rate and a slight appreciation in real terms takes place as well. This is highly visible in the empirical results and can explain that gains from carry trades can be explained mostly by the expected interest rate differential.

Borst and Lardy (2015) explain in more detail, how policymaker in China is intervening on the foreign exchange market. They state that though the "renminbi is less undervalued than during the 2000s, it remains subject to occasional heavy government interference"(p.10).

The last case of South Africa seems to coincide with the results which were observed for the majority of the G6 countries. It might be explained by the fact, that South Africa's central bank is intervening only little on the foreign exchange market, i.e. the rand is considered to be freely floating (as the currencies of the G6 countries are as well). Risk-seeking investors which suffer from low interest rates in the US market invest in short term assets in South Africa. Thus, the market is flooded with liquidity and inflation rises. Regarding the volume of this liquidity shock the policymaker targets inflation differently. Thus, expectations on real interest rates become highly volatile and suffer from uncertainty. This is reflected in the results of the regression on the direct reaction of the exchange rate on the expected real interest rate differential which seems to either appreciate or depreciate taking into account the large confidence intervals. Similar to the case of Brazil, India, and China, there are expected positive gains on carry trades from the US to South Africa, because the interest rates in the latter are simply higher and the exchange rate reacts ambiguously. However, with rising inflation the excess returns turn to losses as then the currency is more likely to strongly depreciate in real terms. This means, the investment in the country is just considered more risky when the interest rate differential exceeds a certain level. How heterogeneous expectations on inflation in South Africa for the time from 2000-2013 actually were is discussed in Kabundi, Schaling, and Some (2015).

Thus, for all BRICS countries the quantitative easing program and a different response of the central banks actually can provide an explanation which might account for the empirical observations. Nevertheless, it has to be noticed that this is just providing a highly simplified picture of the situation and not a detailed analysis. In fact, the actions which were undertaken by the policymakers of the BRICS countries are likely to vary over time and country as well as also might take other effects beyond quantitative easing in the US into consideration. There could also be some kind of 'trial and error' setting in which central banks and markets of emerging economies find out how to efficiently respond to the strong liquidity effects deriving from the unconvential monetary policy in the industrialized countries. Regarding this, policy signaling of the central banks, also that of the Fed, could be another important factor, which is neglected here. Last but not least there have also been quantitative easing programs of other industrialized economies, e.g. that of the european central bank, which have not been taken into account in the two country setting here.

An interesting aspect which is neglected here, but also might play an important role is the impact of capital controls in the BRICS countries which are not discussed in this thesis. In Chamon and Garcia (2016) the effect in Brazil in the aftermath of the financial crisis is investigated. But also the other BRICS countries implemented capital controls and effects of these are analyzed in Pasricha et al. (2015). They can show that particularly after 2008 capital inflow restrictions had an impact on exchange rates.

An interesting investigation of Eichengreen and Gupta (2015) describes the effect of announcements from the Fed to retreat from Quantitative Easing. Their results yield insight into a regime of reduced liquidity in emerging markets and how exchange rates might react on this.

4. Conclusion and Outlook

In this thesis an empirical research is applied using a vector error correction model for estimating expected real interest differentials and ex ante excess returns on carry trades, following the methodology applied in Engel, 2016. Applying this approach on the data reveals that most of the real exchange rates do not show a pattern of mean reversion. Hence, a model which could better reflect the dynamics of the real exchange rate means a strong improvement of the empirical analysis. Nevertheless, it is shown that interest parity in real terms seems to have been violated for each of the BRICS countries' currency for monthly holding periods during the years 2007-2017. Further, it is evident that the countries show different patterns in the interplay between their real exchange rate and real interest rate differential to the US.

The findings for Brazil, Russia, India, and South Africa differ from observations of many articles which find that real interest parity either holds or is systematically violated in a different way. This indicates, that for short term investments in emerging countries there might be circumstances in which neither real interest parity nor the classical interest parity puzzle appear in real terms. In the market environment of the countries and the time frame investigated, a regime of unconventional monetary policy, that is quantitative easing, might play an important role in explaining the unusual observations. When large capital flows from the western countries, in this case the US, enter an emerging economy, stable growth in this country suffers from increased pressure on inflation as well as an appreciation of its currency. It is shown how different counteractions of central banks in the individual countries lead to a distinct pattern of exchange rates and interest rates. However, as quantitative easing in the US already came to an end in 2014, the setting of unconventional monetary policy in the US is not representative for the whole period observed but just for parts of it. It has also been neglected that other industrialized countries or regions, e.g. the Eurozone, have made use of quantitative easing as well. The explanation of the finding is not taking into account further effects on the US or the BRICS countries and does not provide a detailed insight. There might be different regimes, triggered by specific important events, e.g. announcements of the Fed regarding monetary policy in the US or the central banks in the BRICS countries regarding exchange rate stabilization, which could provide further explanations.

An interesting outlook for the explanation of the empirical results given in this thesis regarding the behavior of central banks was to extend the formal model of Engel, 2016 to an asymmetric setting. In particular, the model already contains all the necessary conditions (i.e. shocks on liquidity and monetary shocks) and just needs minor adjustments to explain the findings. By interpreting the observations for the BRICS countries only, it was neglected that the empirical research also showed unusual results for the G6 countries. It is of interest whether liquidity effects can account for these findings as well. Another interesting aspect is to investigate what might happen to inflation, interest rates, and exchange rates of the BRICS and other emerging economies, and how their central banks might react, if the Fed was deciding to systematically reduce its balance sheet. Regarding the importance of the interplay of interest rates and exchange rates in international financial markets and its role in global economic stability and growth, additional research on the effects of liquidity in emerging and developed countries has to be performed.

Appendix

Appendix A.

Tables and Figures

Table A.1.: Augmented Dickey-Fuller Test for a Unit Root

ADF-Test: T=505, lags=7		**exchange rate**	**cons. price diff.**	**int. rate diff.**
Brazil	adf statistic	-1.8916	-2.3668	-5.5848
	p-value	0.6242	0.4230	0.0100
Russia	adf statistic	-2.0752	-2.5450	-3.5251
	p-value	0.5465	0.3476	0.0399
India	adf statistic	-2.2944	-1.5761	-5.7263
	p-value	0.4537	0.7577	0.0100
China	adf statistic	-0.9765	-5.7410	-4.3386
	p-value	0.9425	0.0100	0.0100
South Africa	adf statistic	-1.6745	-2.2943	-2.0181
	p-value	0.7161	0.4537	0.5706
Canada	adf statistic	-1.3760	-2.4813	-2.8808
	p-value	0.8424	0.3746	0.2055
France	adf statistic	-2.8693	-4.1013	-3.9386
	p-value	0.2103	0.0100	0.0121
Germany	adf statistic	-2.8693	-4.8498	-3.9386
	p-value	0.2103	0.0100	0.0121
Italy	adf statistic	-2.8693	-3.0172	-3.9386
	p-value	0.2103	0.1477	0.0121
Japan	adf statistic	-2.1968	-1.8630	-3.8636
	p-value	0.4950	0.6363	0.0158
UK	adf statistic	-2.4095	-1.9769	-2.0739
	p-value	0.4050	0.5881	0.5470

Table A.2.: Johansen Test for cointegration between nominal exchange rates and consumer price differential. H0 is the hypothesis that the number of cointegrating relations is 0, H1 the hypothesis that the number of cointegrating relationships is smaller or equal to 1.

Johansen Test, T=505, lags = 4		Statistic	10%	5%	1%
Brazil	H1	1.643	6.500	8.180	11.650
	H0	10.073	15.660	17.950	23.520
Russia	H1	1.226	6.500	8.180	11.650
	H0	17.290	15.660	17.950	23.520
India	H1	3.087	6.500	8.180	11.650
	H0	8.617	15.660	17.950	23.520
China	H1	6.250	6.500	8.180	11.650
	H0	20.954	15.660	17.950	23.520
South Africa	H1	1.486	6.500	8.180	11.650
	H0	13.681	15.660	17.950	23.520
Canada	H1	1.770	6.500	8.180	11.650
	H0	13.513	15.660	17.950	23.520
France	H1	0.127	6.500	8.180	11.650
	H0	21.251	15.660	17.950	23.520
Germany	H1	1.066	6.500	8.180	11.650
	H0	20.640	15.660	17.950	23.520
Italy	H1	0.069	6.500	8.180	11.650
	H0	12.915	15.660	17.950	23.520
Japan	H1	2.366	6.500	8.180	11.650
	H0	7.447	15.660	17.950	23.520
UK	H1	3.637	6.500	8.180	11.650
	H0	11.043	15.660	17.950	23.520

Table A.3.: VECM estimates for g_{11}

	g_{11} **estimtate**	**left tail 1%**	**left tail 5%**	**left tail 10%**
Brazil	-0.00266	-0.01735	-0.01097	-0.00771
NW s.e.	0.00286			
Russia	-0.00063	-0.01233	-0.00783	-0.00546
NW s.e.	0.00260			
India	-0.00099	-0.00783	-0.00442	-0.00310
NW s.e.	0.00131			
China	-0.00243	-0.01396	-0.00818	-0.00605
NW s.e.	0.00449			
South Africa	-0.00333	-0.02693	-0.01704	-0.01229
NW s.e.	0.00337			
Canada	-0.00551	-0.03419	-0.02291	-0.01714
NW s.e.	0.00708			
France	-0.01622	-0.03449	-0.02000	-0.01539
NW s.e.	0.01108			
Germany	-0.01760	-0.03144	-0.02056	-0.01570
NW s.e.	0.01144			
Italy	-0.01327	-0.02887	-0.01822	-0.01376
NW s.e.	0.01130			
Japan	-0.00462	-0.04217	-0.02758	-0.02191
NW s.e.	0.00447			
UK	-0.00351	-0.02441	-0.01704	-0.01232
NW s.e.	0.01035			

Table A.4.: VECM estimates for g_{21}

	g_{21} estimate	right tail 1%	right tail 5%	right tail 10%
Brazil	0.00001	0.00006	0.00004	0.00003
NW s.e.	0.00001			
Russia	0.00001	0.00007	0.00004	0.00003
NW s.e.	0.00001			
India	0.00004	0.00014	0.00008	0.00005
NW s.e.	0.00002			
China	0.00044	0.00076	0.00049	0.00040
NW s.e.	0.00020			
South Africa	0.00001	0.00009	0.00005	0.00004
NW s.e.	0.00001			
Canada	0.00005	0.00015	0.00009	0.00007
NW s.e.	0.00004			
France	0.00015	0.00023	0.00015	0.00012
NW s.e.	0.00009			
Germany	0.00017	0.00024	0.00015	0.00012
NW s.e.	0.00009			
Italy	0.00017	0.00014	0.00010	0.00007
NW s.e.	0.00007			
Japan	0.00000	0.00017	0.00009	0.00007
NW s.e.	0.00002			
UK	0.00009	0.00021	0.00013	0.00009
NW s.e.	0.00010			

Table A.5.: VECM estimates for $g_{21} - g_{11}$

	$g_{21} - g_{11}$ **estimate**	**left tail 1%**	**left tail 5%**	**left tail 10%**
Brazil	-0.00267	-0.01738	-0.01098	-0.00772
NW s.e.	0.00286			
Russia	-0.00063	-0.01239	-0.00784	-0.00549
NW s.e.	0.00260			
India	-0.00103	-0.00791	-0.00447	-0.00309
NW s.e.	0.00131			
China	-0.00287	-0.01398	-0.00849	-0.00622
NW s.e.	0.00454			
South Africa	-0.00334	-0.02704	-0.01704	-0.01232
NW s.e.	0.00337			
Canada	-0.00556	-0.03427	-0.02299	-0.01722
NW s.e.	0.00707			
France	-0.01637	-0.03463	-0.02007	-0.01546
NW s.e.	0.01112			
Germany	-0.01777	-0.03161	-0.02060	-0.01580
NW s.e.	0.01146			
Italy	-0.01344	-0.02892	-0.01828	-0.01381
NW s.e.	0.01132			
Japan	-0.00461	-0.04221	-0.02760	-0.02211
NW s.e.	0.00447			
UK	-0.00360	-0.02438	-0.01709	-0.01239
NW s.e.	0.01035			

Table A.6.: Mean squared error and Bias of $\hat{\mathbb{E}}_t[\pi_t - \pi_t^*]$ to actual values - BRICS

	BRA	**RUS**	**IND**	**CHI**	**ZAF**
MSE	0.1095	0.2049	0.6883	0.3517	0.1629
Bias	0.0072	0.0008	-0.0095	0.0065	0.0007

Table A.7.: Mean squared error and Bias of $\hat{\mathbb{E}}_t[\pi_t - \pi_t^*]$ to actual values - G6

	CAN	**FRA**	**GER**	**ITA**	**JAP**	**UK**
MSE	0.1059	0.2114	0.2562	0.1048	0.1558	0.2669
Bias	0.0006	0.0021	-0.0014	-0.0010	0.0001	0.0028

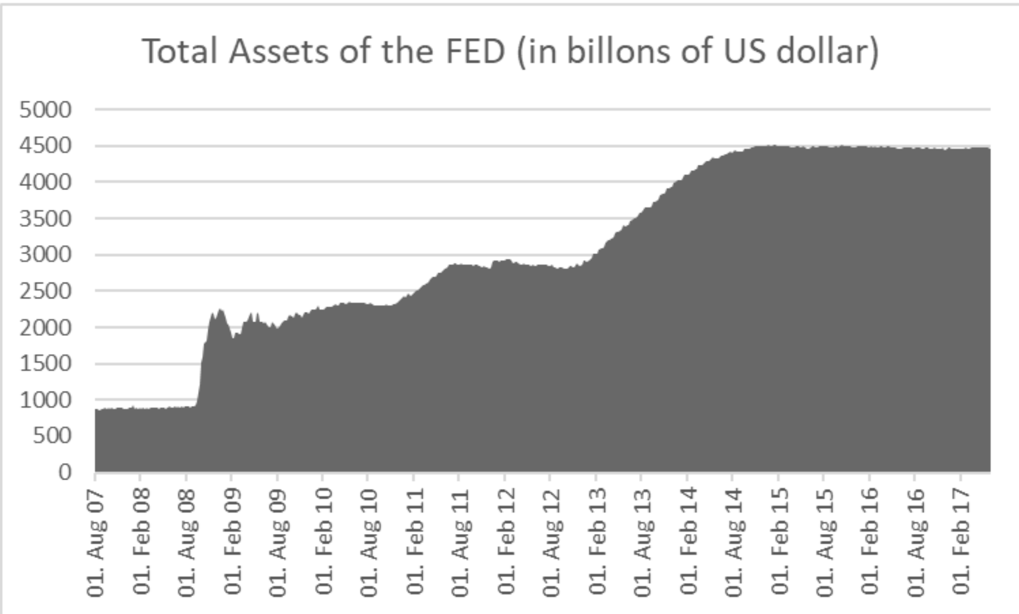

Figure A.1.: Total assets of the Fed from 2007 to 2017. Data is obtained from the homepage of the Fed from the recent balance sheet trends.

Appendix B.

Bootstrap of Table A.3, A.4, and A.5

The significance levels of table A.3, A.4 and A.5 are constructed via the same bootstrapping method as in Engel (2016). First, the Vector Auto Regression Model

$$Y_t = D_0 + D_1 * Y_{t-1} + D_2 * Y_{t-2} + D_3 * Y_{t-3} + D_4 * Y_{t-4} + u_t \tag{B.1}$$

is estimated, where

$$Y_t = \begin{pmatrix} s_t - s_{t-1} \\ (p_t - p_t^*) - (p_{t-1} - p_{t-1}^*) \\ i_t - i_t^* \end{pmatrix}.$$

and the vector D_0 as well as the matrices D_1 to D_4 are all unrestricted. In particular, the shape of equation (B.1) is determined under the assumption, that the nominal interest rate differential is stationary but nominal exchange rate and consumer price differential are not.

Having performed equation by equation regression on (B.1), the parameters of D_0 to D_4 are determined as well as residuals for all t. From the 505 residuals observed, 1005 times a single one is drawn with replacement and equal probability (i.e. 500 additional draws are performed compared to the sample size). After having drawn one, this residual is included in the model of equation (B.1) with its already determined parametrization. Thus, 1005 pseudo observations of Y_t are generated. The last 505 of this pseudo observations are taken as new data in order to construct further estimations of the Vector Error Correction Model (2.5). Repeating this 2000 times and finally ordering the various estimated coefficients from (2.5) by size, yields an estimation of quantiles for g_{11} and g_{21}.

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