Interdepartmental program of postgraduate studies in Business Administration

Master Thesis

An econometric model of EUR/USD exchange rate: What is the role of macroeconomic and financial factors?

Frangos Vasileios

Supervisor: Prof. Costas Karfakis

Submitted as required in order to obtain the Master's degree in Business Administration with specialization in Financial Management

Thessaloniki, 2017

Acknowledgements

First of all, I would like to express my sincere gratitude to my professor Costas Karfakis not only for accepting to supervise my master thesis but also for the knowledge he provided, helping me to uncover interesting questions and the inspiration that he gave me during our classes to study and enrich my knowledge in the world of finance.

Moreover, I would like to thank my family for the unconditional support that gave me this important period of my life as an undergraduate and afterwards as a postgraduate student.

Last but not least, I am really grateful to my companion and BSc in Mathematics, Anastasia for her persistence in encouraging; helping and supporting me in the most demanding moments.

Abstract

Exchange rates have always been a field of interest for economists, fund managers, investors, specialized traders, companies, as well as merchants who would like to buy or sell commodities and other products outside their country, hedge their positions or even speculate from their fluctuations.

The EUR/USD is one of the most important exchange rates; if not the most important globally, owing to the fact that it is the most actively traded currency pair and the huge number of funds and the investors that exist in the Eurozone and in North America. Furthermore, we shall not forget that the price of oil is determined in dollars so a great number of transactions daily take place between these two economic zones involving significant values.

The purpose of this dissertation is to study, based on the theory that determines exchange rates, the effects of macroeconomic and financial factors in the EUR/USD exchange rate. First of all, after a brief literature review that reviews the work that has been already done from researchers concerning our exchange rate, the econometric methodology that we will use is referred. Afterwards, we will move to the empirical analysis where we will study meticulously the relationship between macroeconomic and financial factors and the EUR/USD exchange rate and we will form both the long-term, as well as, the short-term model with independent variables chosen after many tests, mainly with the trial and error method and dependent variable first the logarithm of EUR/USD rate and then the first difference of the latter for our short-term model. Moreover, we will try to forecast with the help of our econometric model this exchange rate after the 2008 financial crisis that led to a great global recession in order to realize the predictability and reliability of our model, its capability to beat the random walk in the short-term level and if there is a possibility for this specific model to be used for future forecasts. Finally, we will conclude our project evaluating our model and analyzing how it could be used for predictions with greater reliability.

Contents

List of Figures

List of Tables

“Beware of geeks bearing formulas”

Warren Buffet

1. Introduction

As it was previously referred, the purpose of this project is to analyze and predict the time series of EUR/USD exchange rate after August 2008 based on a set of macroeconomic and financial variables that we have chosen. Our data set is monthly, separated into two parts; the first one contains information regarding the exchange rate from March 2001 until July 2008 and the second one from August 2008 until May 2016.

For the purpose of our analysis we will use modern econometric methodology including Cointegration Analysis and the Error Correction Model in order to determine the way our model and more specifically our variables in our long term model approach the short-term fluctuations of our exchange rate and what is the degree of the correction between our model and the actual prices per month.

1.1 A brief history of euro and dollar currencies, as well as their exchange rate

On the one hand dollar is one of the most historical currencies in the history of economics. Back in the 1500s in Bohemia (modern Czech Republic) a switch in the usual until then monetary establishment occurred. From tiny gold coins people started to exchange with bigger silver coins in their transactions. Most of these coins came from the Bohemian town of St Joachimsthal, located on today's Czech-German border. This brand new type of coin was called “The Thaler”. Soon enough, this coin was so popular that other countries also started to create an equivalent of the above. Such equivalent in English could be called “the dollar”. In the meantime, Spaniards were really powerful in creating colonies all over the world so their currency “pesos” was widely used for commercial purposes in North America too, with the name “Spanish Dollar” because of the equivalence of “pesos” to the Bohemian coin. It was more popular at this period than the British Pound, which was the official currency, among the North Americans, due to their transactions. After the popularization of “The Thaler” at about 1770s colonies in North America declared their independence. They had to choose between two currencies the British pound as these territories were mainly British and the currency that people used to use all this time there, the dollar. In 1792 the decision had been made and the United States confirmed that from that time “the money of account of the United States shall be expressed in dollars” (Baer, 2015)

On the other hand, the history of the Euro is much more recent. The beginning was noted at the Maastricht Treaty where 12 countries agreed about the creation of the European Union which promoted the development of the Eurozone, the economic and monetary union among many European countries. (The Editors of Encyclopedia Britannica, 2007). The Euro as an existence firstly appeared on January 1st 1999 in 11 of the 15 EU member states and began trading at $1.1747 and on the 1st of January 2002 the Euro notes and coins become legal tender in the 12 Eurozone countries - Greece is the 12th member. (Telegraph Media Group, 2010)

From this point, until now, many fluctuations for this major exchange rate have been noted. The most significant was on the 26th of October 2000, when Euro hits a record low of $0.8225. On the other hand on February 27, 2008 Euro traded above $1.50 after the statement of FED's chairman Ben Bernanke that rates would be cut due to upcoming risks. Below, there is a figure presenting the history of our exchange rate and its significant fluctuations from 1990 until 2016.

Figure 1: Euro (EUR) to U.S. dollar (USD) average exchange rate from 1999 to 2016 (ECB, 2017)

2. Literature Review

There has been a great research among scientists about the EUR/USD as it is one of the most important exchange rates in the forex market. The main reason for this is the financial zones that these two currencies represent as on the one hand we have the euro that represents the Eurozone, or else the economy of Europe in a significant degree, and on the other hand, the US dollar that represents the economic and financial situation of the USA. Consequently, by currency pairs, the EUR/USD is the most actively traded. Of course, we cannot afford to neglect that the US dollar is the representative of oil as the demand and supply of barrels of oil are referred in US dollars.

One of the first attempts to describe the EUR/USD exchange rate and the driving forces, in the medium and long term, between these two currencies was made from Jorg Clostermann and Bernd Schnatz, who constructed a “synthetic” euro for the period from 1975 to 1998 to compare it with the US dollar and how this hypothetical exchange rate would conduct. This synthetic euro was calculated as a geometrically weighted average of the dollar exchange rates of individual EMU currencies. The variables that delineated this exchange rate were the international real. Interest rate differential, relative prices in the traded and non-traded goods sectors, the real oil price and the relative fiscal position. With the help of an equation error correction model they came to some really interesting conclusions like that except the prices of goods-services and their differential between these two economic zones, interest rates and their differentials as well as price of oil can affect this exchange rate. Moreover, for the medium and long term the single equation error correction model outperformed the random walk in terms of prediction. (Schnatz, 2000) .

A different approach has been noted from Dunis and Williams who used the fixed EUR/DEM conversion rate agreed in 1998, combined with the USD/DEM daily market rate, analyzing their ex- Euro data sets. Their methodology was innovative as they used neural network models for their study, despite the limitations and potential improvements; it produced more reliable results, in terms of forecasting, than the traditional ways that had been studied until that point (Christian Dunis, 2002). Another econometric approach has been conducted from Weisang and Awazu who tried to investigate the exchange rate with the help of ARIMA models providing a framework for researchers to practice the above mentioned methodology. Completing their project they concluded that their model does not contradict the efficient market hypothesis exhibiting characteristics close to the random walk theory but unfortunately doesn’t succeed in terms of making valid and accurate forecasts (Guillaume Weisang, 2008).

Furthermore, Sartore, Trevisan, Trova and Volo constructed a EUR/USD econometric -area wide- model in Vector Error Correction form for forecasting purposes. Interest rate differential, differential between US and Euro GDP annual growth and this of the real public debt were the main variables in this model that produced satisfactory results. The synthetic US dollar/Euro nominal exchange rate that was used was the one produced by Warburg Dillon Read an investment bank created by the Swiss Bank Corporation as the data sets they analyzed were before the 1st of January of 1999 (Domenico Sartore, 2002). To continue, Paul de Grauwe investigated our exchange rate from the start of 1999 until May 2000 when Euro marked a significant decline of almost 25%. De Grauwe noticed that this phenomenon was caused neither by the economic fundamentals (growth of GDP, production, inflation rate) that had been regarded as the major driving factors of the exchange rates, nor by bad news for the Eurozone concluding that EUR/USD exchange rate is a much more complex system to forecast. The psychology of investors including their fears and expectations and uncertainty about future events and how will they be translated in economic terms, play an important role for him (Paul De Grauwe, 2000).

The subject was approached theoretically too, by Li Wenhao who analyzed the determinants of EUR/USD exchange rate, the competition between Euro and Dollar after the emergence of Euro. Concluding, he made some brief predictions about the future of Euro, as well as of our exchange rate (Wenhao, 2004). Moreover, Lazos Thomas studied the validity of three basic theories regarding exchange rates and the application of one of them in the EUR/USD rate. The uncovered interest parity, the covered interest parity and the efficiency of forex market were analyzed and the latter one was tested from January 2002 until December 2010. The efficiency of forex market declares that the forward exchange rate is an unbiased estimator of the future spot exchange rate. Comparing these two pairs he concluded that we cannot accept the efficient forex market hypothesis as there are many factors such as interest rates, the psychology of investors from everyday news that are not included (Thomas, 2011).

In addition to the above, Asmarah Jamaleh introduced a linear error correction model based on fundamentals like short interest rates, gross domestic product growth expectations and inflation differentials and a non-linear model in order to explain and predict the behavior of the EUR/USD exchange rate. The conclusion of the researcher was that both the linear and non-linear model worked in a satisfactory way and that indeed some rather important fundamentals drive this rate, interestingly, in a non-linear mechanism (Jamaleh, 2002). Another attempt from Sartore, Trevisan, Trova and Volo has been made for predicting the EUR/USD exchange rate with the help of a multi country area econometric model, instead of the area wide first model. This specific model was built in Vector Error Correction form and used data from three European countries only: Germany, France and Italy and common variables like: annual real GDP growth rate, consumer price index to producer price index, ratio of government surplus or deficit and the GDP, ratio of export unit value to import unit value and finally annual real M3 growth rate. The above mentioned scientists came to the conclusion that the multi country model outperformed both the area wide model and the random walk in terms of predictability. The real exchange rate was the same as in their previous paper that is to say the synthetic US dollar/Euro nominal exchange rate by Warburg Dillon Read (Domenico Sartore, 2003).

Ghalayini later deviated from the above and constructed an ARIMA model studying the volatility of EUR/USD exchange rate time series in the long run using the inflation differential, interest rate differential, business cycles and the money aggregates differential. As far as the short run is concerned he used a Vector Error Correction Model acquiring satisfactory results (Ghalayini, 2014). To continue, Karfakis investigated the existence of an empirical link between the dollar price of the Euro and monetary fundamentals using VAR analysis and an Error Correction Model for the short run and managing to outperform the random walk (Karfakis, 2007)

3. Econometric Methodology

In this section we will investigate the econometric methodology that we will utilize later in the EUR/USD exchange rate time series model and our macroeconomic and financial variables that we are planning to use for it. Long term equilibrium will be established between our dependent and independent variables if they are simultaneously integrated of the same order (usually of order 1) (Engle & Granger, 1987). In order to check the above scenario we must perform a stationarity test in our variables with the aid of the unit root test (David Dickey, 1979) . To continue, discovering the existence of cointegration among our variables enables us to perform the Ordinary Least Squares (OLS) Method and our regression in order to determine the connection between our exchange rate and the variables we chose by examining the sign of the coefficients, their statistical significance and if they agree with our known, so far, economic theory. Afterwards, we shall try to analyze the short-run dynamics of this relationship by using an Error Correction Model and checking the residuals from our long-term model. The residuals will help us understand the connection between the variables we used in the long term model and the actual fluctuations in the short-term level and how closely our model can approach the real price changes of every month since we use monthly data sets in our project. We will explain later in our project the specific process we follow in detail.

3.1 Stationarity

It is essential for our econometric analysis that the time series under consideration is stationary. A time series is called stationary if the mean and the variance are constant over time and the value of covariance between two time periods depends only on their distance and not on the time during which the covariance is calculated (Gujarati, 2004). Although we cannot perform econometric analysis in non-stationary time series, as it is characterized by a trend, with the help of the Cointegration method we can “combine” the non-stationarity of our variables, also called integrated of order 1 (usually), and present a stationary time series which can be analyzed as long as its residuals are integrated of order 0, which means stationary.

Below there is an example of a time series where a non-stationary deterministic process becomes stationary after removing the trend:

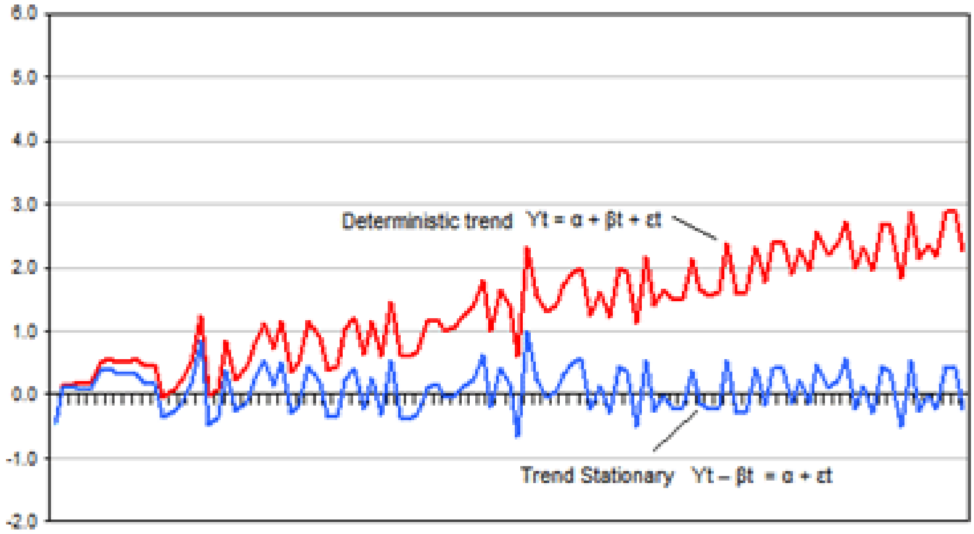

Figure 2: Detrending a non-stationary process (Iordanova, 2007)

Why is stationarity important after all?

First of all, in stationary time series one shock (unexpected event) declines in the passage of time whereas in non-stationary series a shock at time t is followed by equivalent changes in the future periods. Moreover, it is really often that non-stationary variables may produce a spurious regression with invalid R^2 (unexpectedly high) which is the estimator of our model. Last but not least in the case of non-stationarity the assumptions of linear regression cannot be applied and we cannot use t and F statistic distributions.

Later on this chapter we will study the test for stationarity with the help of the unit root method and cointegration more meticulously.

3.2 Unit Roots and Cointegration

Let us that y_t and x_t are the logs of the levels of the variables Y_t and X_t which are linked by the following linear model:

$$y_t = \alpha + \beta x_t + u_t \quad (1)$$

If both variables are not stationary, they contain unit root and we cannot use an OLS estimator to obtain the parameter values α, β because the estimator is not efficient. In this case we should use cointegration analysis to test hypothesis about α, β (before conducting cointegration analysis we must test for unit roots).

To test for non stationarity we employ the following model suggested by Dickey-Fuller:

$$z_t = \gamma + \delta t + \rho z_{t-1} + \varepsilon_t \quad , where\ z_t = (y_t, x_t) \quad (2)$$

and test the null hypothesis that $\rho = 1$ against the alternative that $\rho \neq 1$. This is the so called Dickey Fuller (DF) unit root test.

If the error term is serial correlated then we augment the equation (2) with lagged first difference, that is $\Delta z_{t-j}\ where\ j = 1,2,3 \ldots, n\ number\ of\ lags,$ of the dependent variable in order to absorb serial correlation and then we conduct the unit root test. This is the, so called, augmented Dickey Fuller test (ADF).

Given non stationarity for both y_t and x_t then we run regression (1) and test whether u_t are integrated of order 1 against the alternative hypothesis that u_t are I(0). If u_t are I(0) independent and normally distributed, it is implied that Y_t and X_t are cointegrated series.

3.3 Error Correction Model

As we previously mentioned with the cointegration method we can estimate the long term relationship between two or more variables. Precisely, if two variables are cointegrated there is long term equilibrium between them (Engle & Granger, 1987). On the contrary in the short-term these variables may be in disequilibrium. This disequilibrium can be expressed with the help of the Error Correction Model (ECM). The error of our disequilibrium can be used to connect the short-term with the long-term period.

To continue, under cointegration there exists an error correction model of the following form:

$$\Delta y_t = \varphi_0 + \varphi_1 \Delta y_{t-1} + \varphi_2 \Delta x_t - \varphi_3 u_{t-1} \quad (3)$$

where Δy_t , Δx_t are the first differences of variables y_t and x_t which are integrated of order 1. The first differences are I(0), as well as, the error term u_t, so we can estimate the above equation with the help of linear regression.

Practically, we are moving to the first differences connecting the long-term with the short-term model with the help of the error term and its coefficient. We are examining if the variables in our long term model are able to explain the short-term fluctuations and how quickly is corrected the divergence between actual exchange rates with our models' ones in the short-term.

4 Empirical Analysis

4.1 The relationship between EUR/USD and macroeconomic – financial factors

It is well known from economic theories that there are many macroeconomic and financial factors that can affect an exchange rate like the EUR/USD which is the most actively traded exchange rate in the forex market.

First of all the price differential between the USA and the Eurozone is really essential for the researchers, who try to analyze EUR/USD and its fluctuations. It is more than obvious nowadays, after so much research, that the country with lower consumer prices is more competitive and causes an increase in its currency in correspondence to other currencies. We shall not forget that the first logarithmic differences of the index CPI (consumer price index) are the inflation rate.

Moreover, the differential in interest rates can be really influential as higher interest rates attract the foreign capital and cause the exchange rate to rise. Suppose ECB decides to increase the deposit interest rate of Euro relative to what FED has decided for US dollar. Capitals will move from many countries, as well as the USA, to Europe and in the short term our exchange rate will rise. After some period of time, funds will return and the exchange rate will gradually decrease.

Another crucial macroeconomic factor for the determination of the exchange rate is the balance of trade between a country and its trading partners. In our case, we analyze countries that compose the Eurozone and the USA trading activities. When, for instance, countries from Eurozone export more and import less than the USA, Euro will appreciate against dollar and vice versa. In this point, we shall not forget that the price of oil is expressed in US dollars and its fluctuations in prices can affect significantly our exchange rate.

To continue, there are other macroeconomic factors as well that can play an important role in determining the EUR/USD exchange rate, such as public debt, governmental long term bond rates (along with their yield curves), unemployment and political stability. The higher the bond rates the more insecure a country is regarded from investors and this can lead to a depreciation of one currency against another.

Finally, stock markets and various indices in Euro land, as well as in the USA, can affect in a significant way the EUR/USD rate. A surge of the Dow Jones or the SP500 can cause an appreciation of US Dollar against Euro, due to psychological reasons mainly among investors. Similarly, an increase of the DAX index or the CAC can cause an appreciation of Euro against the US Dollar. To conclude, of equal meaning are indices like the VIX, the index that represents the volatility of SP500 options, the Russell 3000, which is a capitalization weighted stock market index that functions as a benchmark for the entire US stock market and the NASDAQ index for Eurozone which represents the financial situation of this area.

4.2 Data

The data we used for our project has been taken from www.quandl.com and https://fred.stlouisfed.org/ and the software we used is Gretl econometric packet http://gretl.sourceforge.net/ . We took monthly data from March 2001 until May 2016 in order to have a sufficient sample and derive reliable results.

According to theory and following numerous attempts we used macroeconomic and financial variables both for our long term and our short term model in order to have a satisfactory econometric model that could determine and even forecast the EUR/USD exchange rate time series.

The two models we finally decided to investigate for the EUR/USD time series analysis are:

$$e_t = b_0 + b_1 MI_t + b_2 IRD_t + b_3 NI_t - b_4 GBR_t - b_5 SP500_t + \omega_t$$

For our long term model, where:

- Misery index stands for USA unemployment + inflation rate
- 3month differential interbank rate stands for the differential interest rate between Euro deposits and US Dollars deposits as defined by the ECB and the FED (Euro Rate – US Dollar Rate)
- Nasdaq index for Eurozone stands for a float adjusted market capitalization-weighted index designed to track the performance of securities assigned to the Eurozone
- 10year German bond rates stand for the rate of 10year governmental German bonds
- SP500 stands for the well-known index
- ω_t stands for the error term of our model
- b_1, b_2, b_3, b_4, b_5 parameters

All variables are expressed in logarithmic scale excluding these which contain rates.

For our short-term model where we now have first differences the equation is the following:

$$\Delta e_t = +c_1 \, \Delta \, IUSA_t - c_2 \Delta \, SP500_t - c_3 \Delta \, DJ_{t-1} + c_4 \Delta NI_t + c_5 \Delta NI_{t-1} - c_6 \Delta GBR_t + c_7 \Delta \, e_{t-1} - c_8 \omega_{t-1} + v_t$$

- *Δ* Imports USA stands for the first logarithmic differences of Imports price Index of USA
- *Δ* sp500 stands for the first logarithmic differences of sp500
- *Δ* DowJonesIndex stands for the first logarithmic differences of Dow Jones with time lag of 1 period
- *Δ* Nasdaq Index For Eurozone stands for the first logarithmic differences of Nasdaq Index for Eurozone along with time lag of 1 period
- *Δ* 10year German bond rates stands for the first differences of 10 year governmental German bond rates
- *Δ* e_t stands for the first logarithmic difference of our exchange rate with time lag of 1 period
- ω_t stands for the residuals of our long term model (with time lag of 1 period) that have to be accompanied with negative coefficient for purposes of dynamic stability
- v_t stands for the error term of our model
- $c_i \; for \; i = 1 - 8$ parameters

It will be shown later that there is lag in our dependent variable as well as in the Dow Jones index variable and the Nasdaq Index variable which is not strange as past performances of our mentioned above variables can definitely affect their future performances.

Below, there is a series of graphs representing our exchange rate during this period, the variables we used to determine it and their first differences. Some variables are used only in the long-term model or in the short term model for purposes of correlation. In this point it is important to note that for our econometric analysis it is crucial to have the logarithm of our dependent and independent variables (except that from the interest rates) for our model for scaling purposes mainly (have them expressed in a similar way, in other words) as we have variables with different sizes, indices and we would like, somehow, to create a linear regression among them. As far as our short term model is concerned we can have an image by computing the first differences of these logarithms. As we will see later, our long-term model is non-stationary and our short-term stationary.

Figure 3: EURO/DOL exchange rate from March 2001 to May 2016

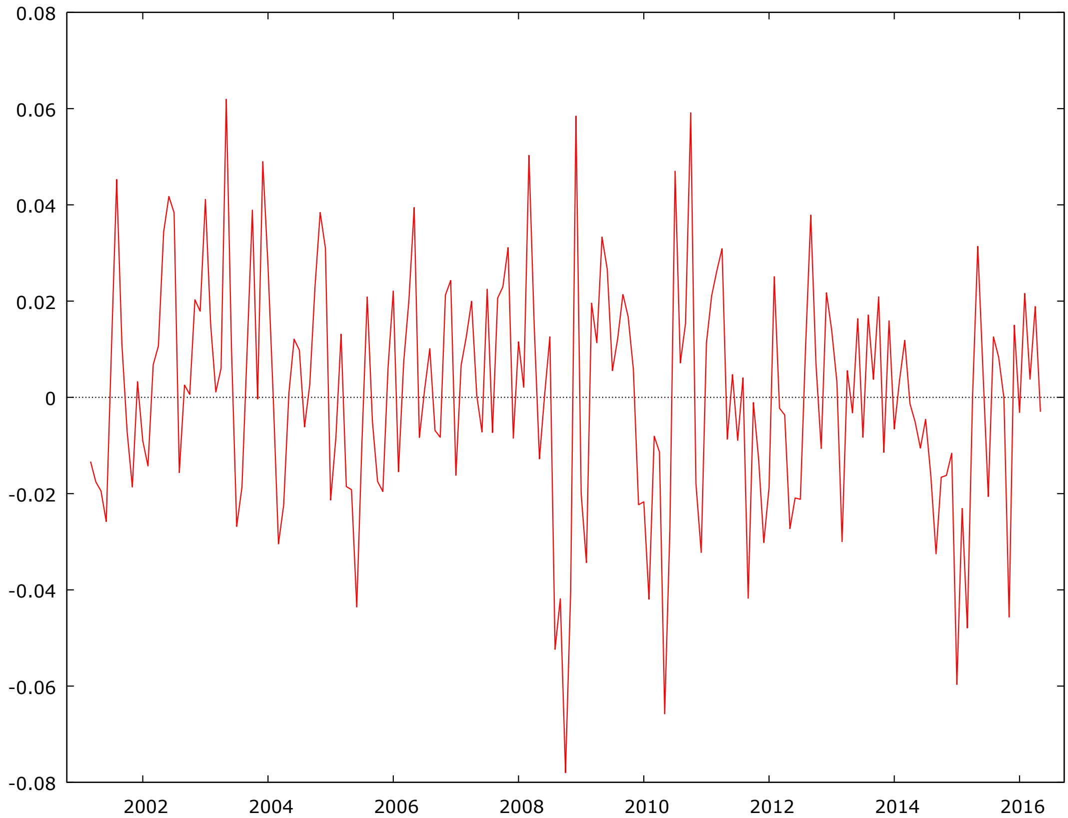

Figure 4: First Differences of EUR/USD exchange rate logarithm

Figure 5: Nasdaq Index for Eurozone

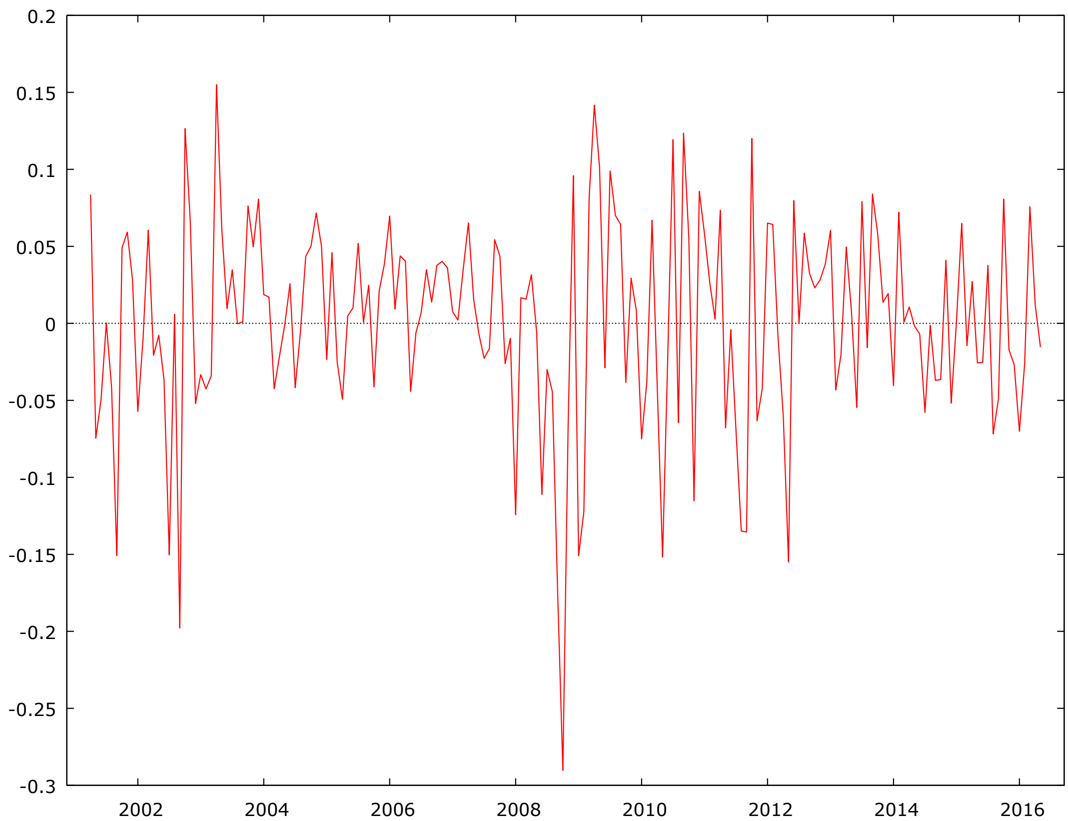

Figure 6: First Differences of Nasdaq Index Logarithm

Figure 7: 10 Year German Bond Interest Rates

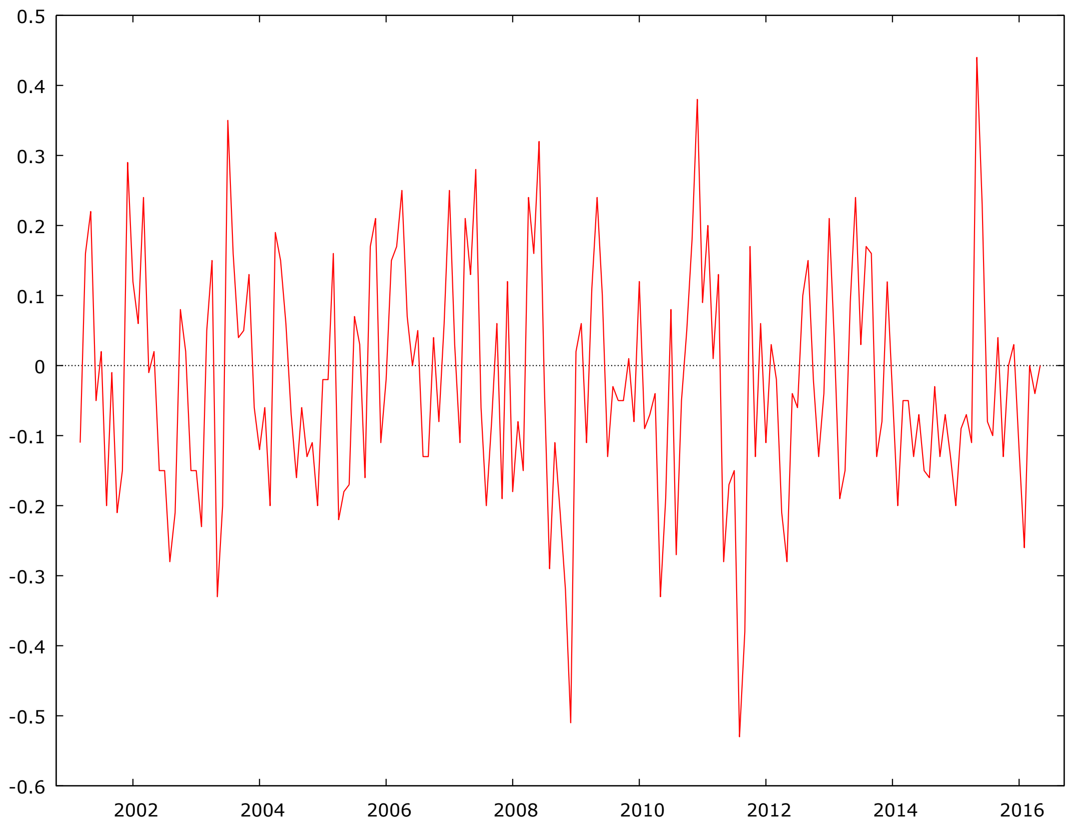

Figure 8: First Differences of 10 Year German Bond Interest Rates

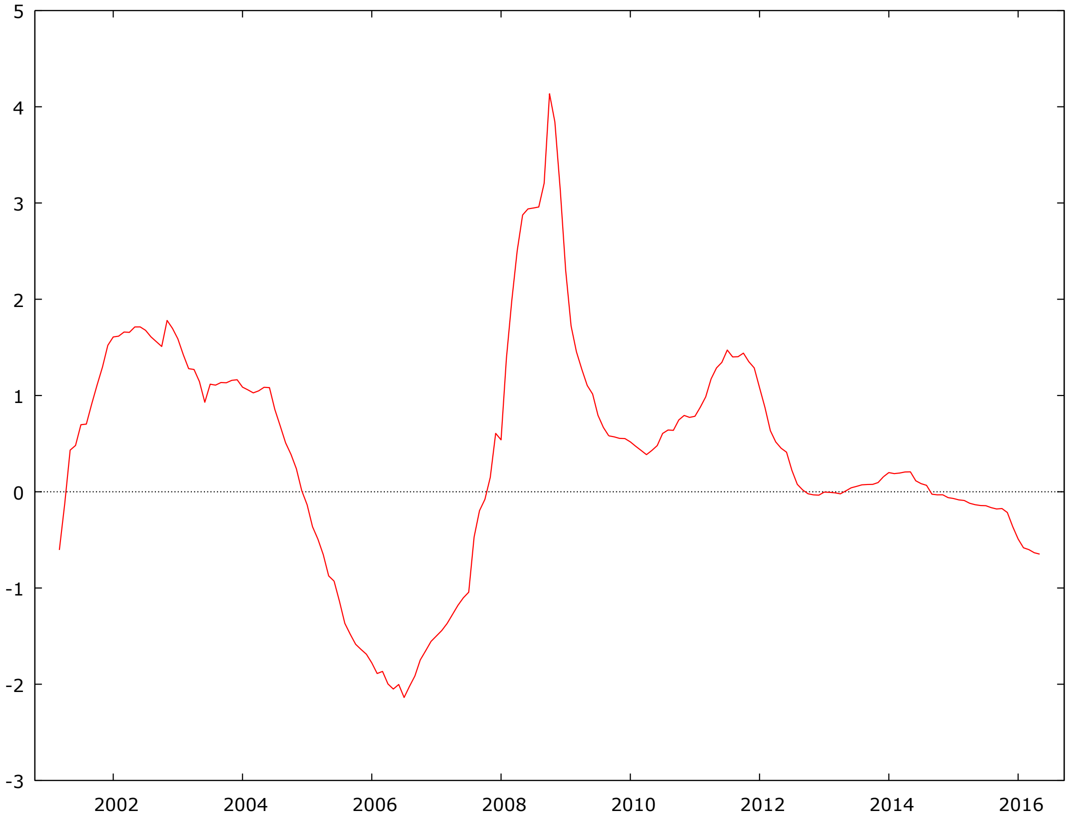

Figure 9: 3moth differential Interest rate between Euro and US Dollar (Euro - USD)

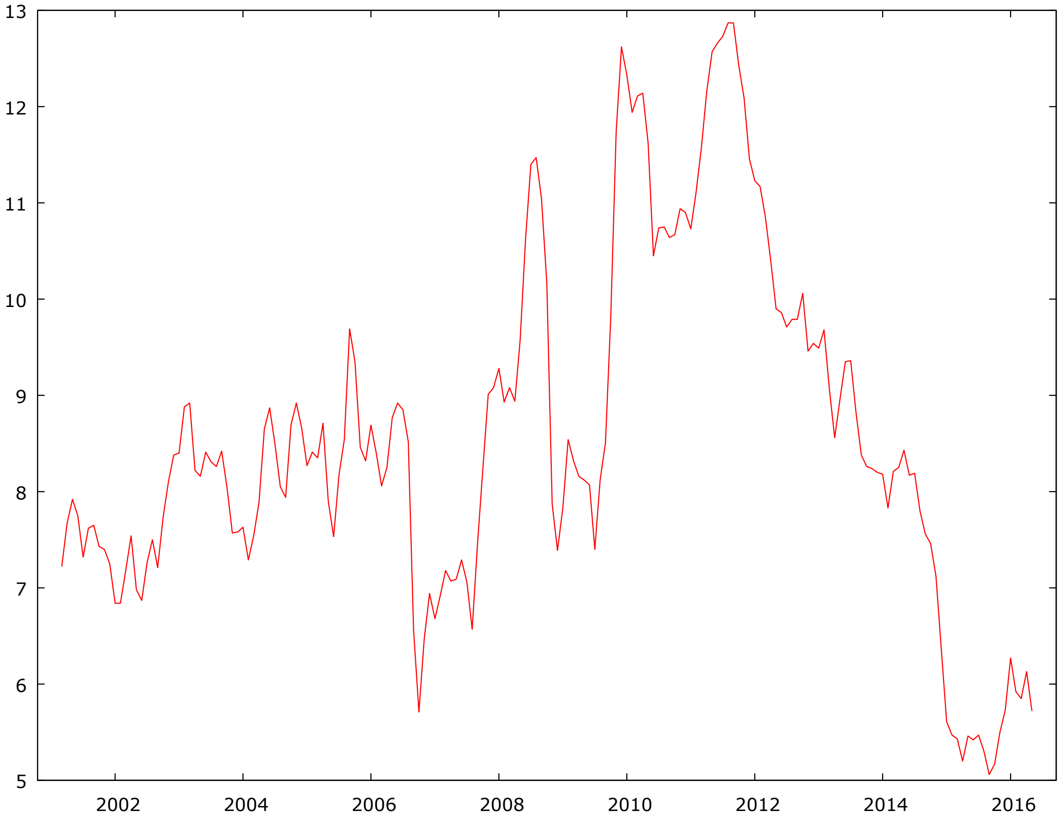

Figure 10: Misery Index for the USA

Figure 11: SP500 index

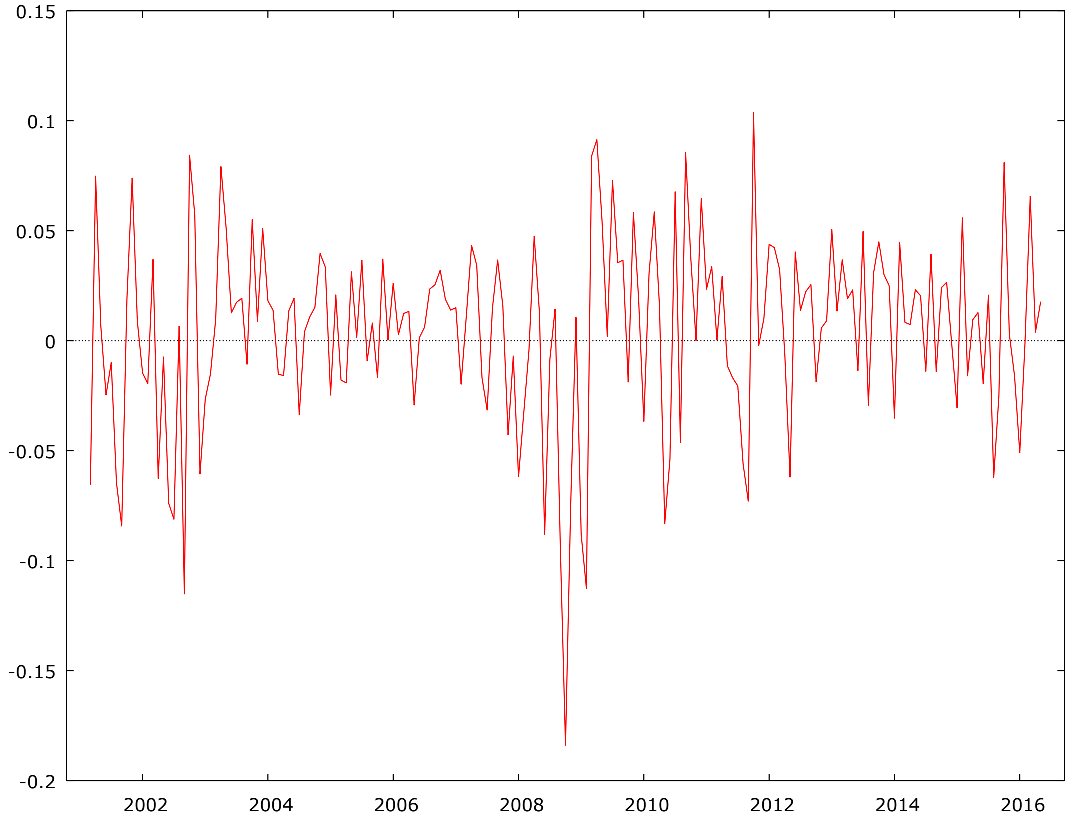

Figure 12: First Differences of SP500 index logarithm

Figure 13: Dow Jones Index

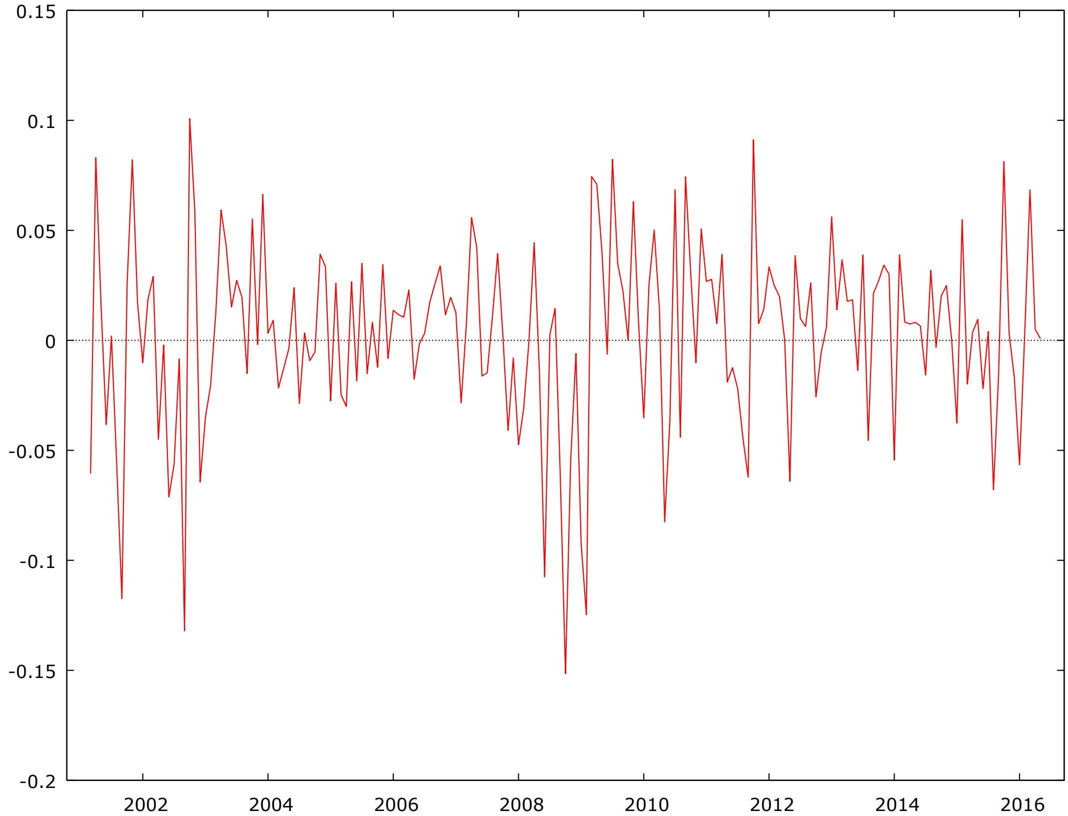

Figure 14: First Differences of Dow Jones Index logarithm

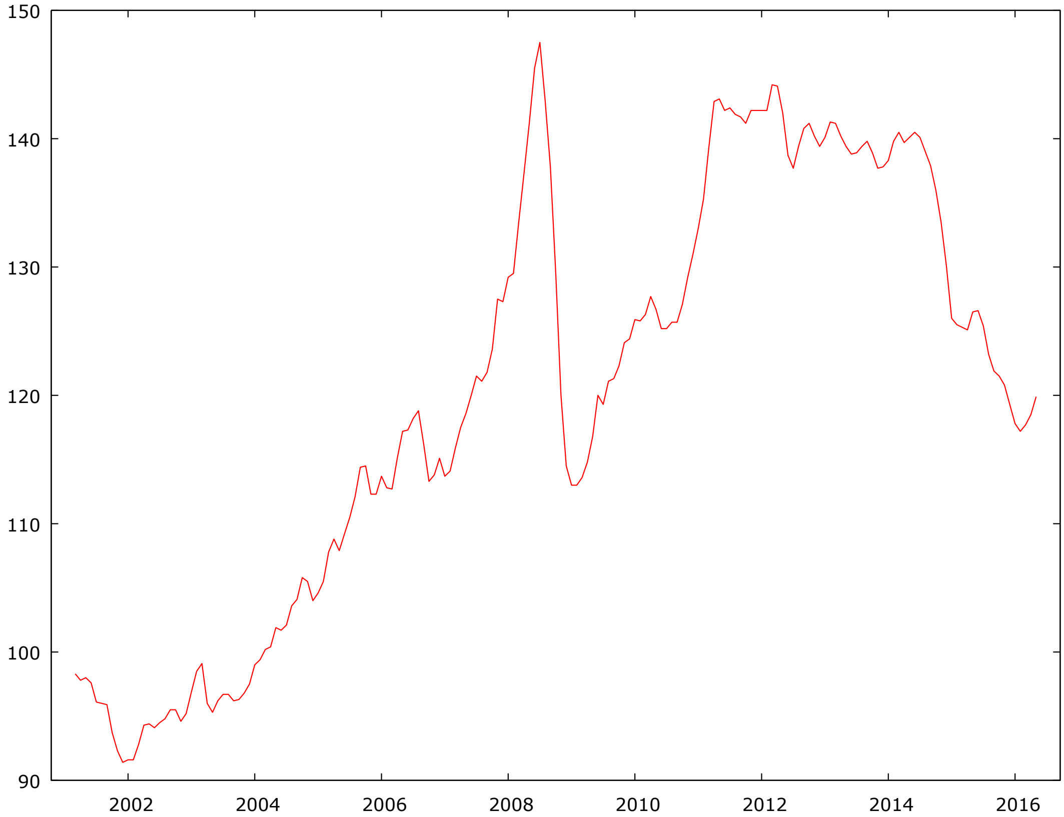

Figure 15: Imports price index for USA (all commodities)

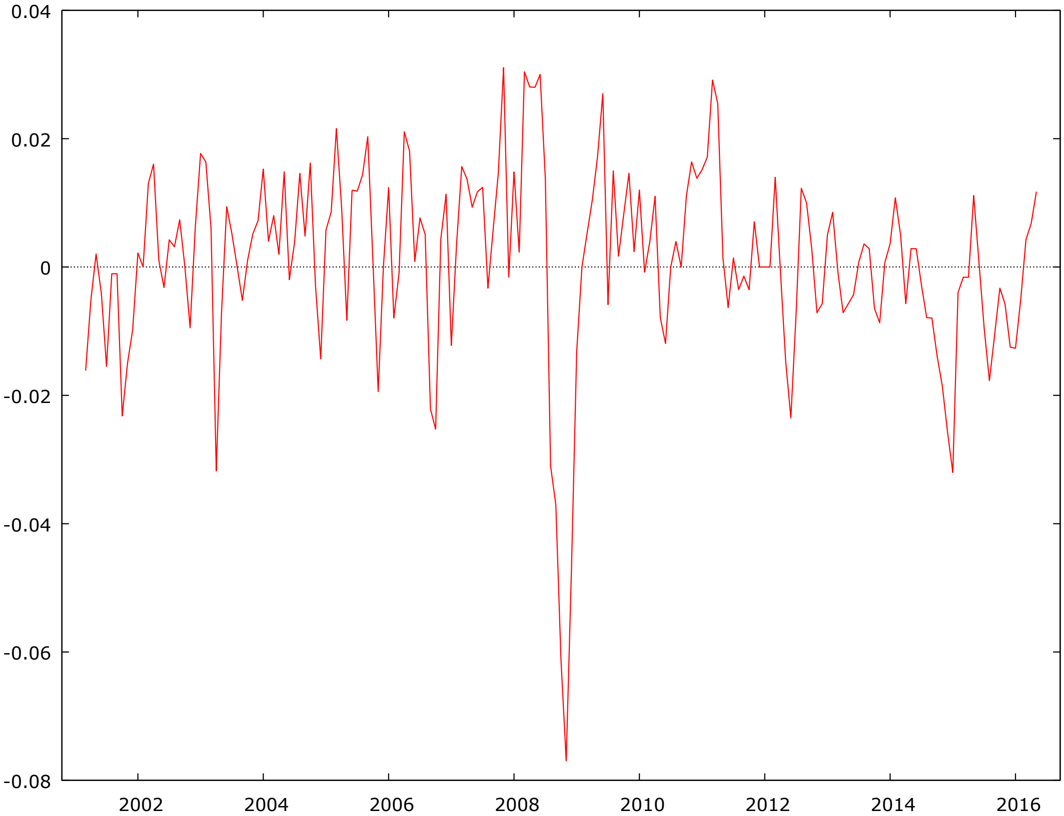

Figure 16: First Differences of logarithm of Imports price index for USA (all commodities)

4.3 Unit Root Test

Having our variables plotted, we can notice that, if not all of them, at least most of them are not stationary in their levels since their mean does not seem to be zero, the variance does not look like stable and the covariance depends on the specific time that the observation is made.

Consequently, we need a test for the stationarity of our variables in order to confirm our hypothesis. The test augments the examined equation by adding the lagged values of the dependent variable for purposes of clearing the autocorrelation of the residuals. The null hypothesis of this test is that there is a unit root so the variable is non-stationary. At this point we will examine each of the variables that we used both in the long-term model as well as in the short-term model and for the following tables we will check the test with the constant and trend model. Keeping in mind that our null hypothesis is that there is a unit root and that prices for p-value below 5% or in some cases 10% we reject the null hypothesis and accept the alternative one or similarly for price of ADF t-statistic below -3,90 we act likewise.

Table 1: ADF Test for EUR/USD exchange rate

```
Augmented Dickey-Fuller test for l_EURODOLLAR
including one lag of (1-L)l_EURODOLLAR
(max was 14, criterion AIC)
sample size 211
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.016328
  test statistic: tau_c(1) = -1.56056
  asymptotic p-value 0.5029
  1st-order autocorrelation coeff. for e: 0.017

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0193222
  test statistic: tau_ct(1) = -1.51092
  asymptotic p-value 0.8263
  1st-order autocorrelation coeff. for e: 0.017
```

We can affirm with certainty that there is a unit root as p-value is 0.8263 and ADF t-statistic is -1.51092 so our variable is non-stationary.

Table 2: ADF Test for Nasdaq Index for Eurozone

```
Augmented Dickey-Fuller test for l_NasdaqIndexEU
including 3 lags of (1-L)l_NasdaqIndexEU
(max was 14, criterion AIC)
sample size 183
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0451988
  test statistic: tau_c(1) = -2.26096
  asymptotic p-value 0.185
  1st-order autocorrelation coeff. for e: -0.016
  lagged differences: F(3, 178) = 2.860 [0.0384]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0507098
  test statistic: tau_ct(1) = -2.35584
  asymptotic p-value 0.403
  1st-order autocorrelation coeff. for e: -0.017
  lagged differences: F(3, 177) = 2.943 [0.0345]
```

We can declare that there is a unit root as the p-value is 0.403 and the ADF t-statistic -2.35584 respectively so the variable is non stationary.

Table 3: ADF Test for German Bond Rates

```
Augmented Dickey-Fuller test for germbondsrates
including one lag of (1-L)germbondsrates
(max was 14, criterion AIC)
sample size 207
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.00108913
  test statistic: tau_c(1) = -0.139624
  asymptotic p-value 0.9434
  1st-order autocorrelation coeff. for e: 0.015

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0668709
  test statistic: tau_ct(1) = -3.47906
  asymptotic p-value 0.0416
  1st-order autocorrelation coeff. for e: 0.015
```

In the above case we can see that there is no unit root since p-value is 0.0416 and ADF t-statistic -3.47906 which means a little higher than the critical price of -3.90 so the variable is stationary and we reject the null hypothesis. However this, as it will be examined later causes no problem in our cointegration analysis.

Table 4: ADF Test for Interbank 3 Month Differential Interest Rate

```
Augmented Dickey-Fuller test for interbankrate3month
including 9 lags of (1-L)interbankrate3month
(max was 14, criterion AIC)
sample size 201
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   estimated value of (a - 1): -0.0294331
   test statistic: tau_c(1) = -2.95952
   asymptotic p-value 0.03886
   1st-order autocorrelation coeff. for e: 0.067
   lagged differences: F(9, 190) = 14.808 [0.0000]

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   estimated value of (a - 1): -0.0297656
   test statistic: tau_ct(1) = -2.93009
   asymptotic p-value 0.1528
   1st-order autocorrelation coeff. for e: 0.067
   lagged differences: F(9, 189) = 14.220 [0.0000]
```

The 3 month differential interest rate variable is non-stationary as we can notice from the table above since its p-value is 0.1528 and the ADF t-statistic is -2.93009. Thus, we accept the null hypothesis.

Table 5: ADF Test for Misery Index

```
Augmented Dickey-Fuller test for l_MiseryIndex
including 12 lags of (1-L)l_MiseryIndex
(max was 14, criterion AIC)
sample size 198
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   estimated value of (a - 1): -0.0176691
   test statistic: tau_c(1) = -0.895315
   asymptotic p-value 0.7904
   1st-order autocorrelation coeff. for e: -0.011
   lagged differences: F(12, 184) = 8.620 [0.0000]

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   estimated value of (a - 1): -0.00522751
   test statistic: tau_ct(1) = -0.255012
   asymptotic p-value 0.9919
   1st-order autocorrelation coeff. for e: -0.027
   lagged differences: F(12, 183) = 8.954 [0.0000]
```

Misery index is a non-stationary variable with unit root, as we observe from the table above. Its p value is 0.9919 and its ADF t-statistic price -0.255012. Therefore we accept the null hypothesis.

Table 6: ADF Test for SP500

```
Augmented Dickey-Fuller test for l_sp500index
including 3 lags of (1-L)l_sp500index
(max was 14, criterion AIC)
sample size 207
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.00173725
  test statistic: tau_c(1) = -0.171189
  asymptotic p-value 0.9397
  1st-order autocorrelation coeff. for e: -0.008
  lagged differences: F(3, 202) = 1.800 [0.1484]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.02829
  test statistic: tau_ct(1) = -1.82724
  asymptotic p-value 0.6917
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(3, 201) = 1.909 [0.1293]
```

Another variable that is non-stationary in our long term model is the SP500 index since according to the table above, its p-value is 0.6917 and ADF t-statistic -1.82724. Therefore we must accept the null hypothesis of the existence of a unit root.

In this point of our project, it is worth mentioning that the following unit root tests with the ADF methodology will conclude to stationary variables since we have the first logarithmic differences of non-stationary variables, except the variable for German bond rates which is already stationary. The tables below will confirm the above mentioned theory.

Table 7: ADF Test for First Differences of EUR/USD exchange rate

```
Augmented Dickey-Fuller test for d_l_EURODOLLAR
including one lag of (1-L)d_l_EURODOLLAR
(max was 14, criterion AIC)
sample size 210
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.779625
  test statistic: tau_c(1) = -9.47261
  asymptotic p-value 1.586e-017
  1st-order autocorrelation coeff. for e: 0.001

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.782799
  test statistic: tau_ct(1) = -9.48492
  asymptotic p-value 9.092e-018
  1st-order autocorrelation coeff. for e: -0.000
```

Table 8: ADF Test for First Differences of USA Imports Price Index for all commodities

```
Augmented Dickey-Fuller test for d_l_InportsUSA
including one lag of (1-L)d_l_InportsUSA
(max was 14, criterion AIC)
sample size 208
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.439393
  test statistic: tau_c(1) = -7.23844
  asymptotic p-value 7.389e-011
  1st-order autocorrelation coeff. for e: 0.007

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.447237
  test statistic: tau_ct(1) = -7.30009
  asymptotic p-value 3.219e-010
  1st-order autocorrelation coeff. for e: 0.007
```

Table 9: ADF Test for First Differences of SP500 index

```
Augmented Dickey-Fuller test for d_l_sp500index
including 2 lags of (1-L)d_l_sp500index
(max was 14, criterion AIC)
sample size 207
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.849507
  test statistic: tau_c(1) = -7.38532
  asymptotic p-value 2.887e-011
  1st-order autocorrelation coeff. for e: -0.008
  lagged differences: F(2, 203) = 1.776 [0.1719]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.913643
  test statistic: tau_ct(1) = -13.1657
  p-value 3.757e-022
  1st-order autocorrelation coeff. for e: 0.010
```

Table 10: ADF Test for First Differences of Nasdaq Index for Eurozone

```
Augmented Dickey-Fuller test for d_l_NasdaqIndexEU
including 0 lags of (1-L)d_l_NasdaqIndexEU
(max was 14, criterion AIC)
sample size 185
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.882426
  test statistic: tau_c(1) = -12.0725
  p-value 5.708e-020
  1st-order autocorrelation coeff. for e: 0.019

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.882401
  test statistic: tau_ct(1) = -12.0383
  p-value 3.369e-019
  1st-order autocorrelation coeff. for e: 0.019
```

Table 11: ADF Test for First Differences of Dow Jones Index

```
Augmented Dickey-Fuller test for d_l_DowJones
including 0 lags of (1-L)d_l_DowJones
(max was 14, criterion AIC)
sample size 185
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.917584
  test statistic: tau_c(1) = -12.5349
  p-value 9.362e-021
  1st-order autocorrelation coeff. for e: 0.027

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.921368
  test statistic: tau_ct(1) = -12.5358
  p-value 4.189e-020
  1st-order autocorrelation coeff. for e: 0.026
```

Table 12: ADF Test for First Differences of German Bond Rates

```
Augmented Dickey-Fuller test for d_germbondsrates
including 4 lags of (1-L)d_germbondsrates
(max was 14, criterion AIC)
sample size 203
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.81665
  test statistic: tau_c(1) = -6.86254
  asymptotic p-value 7.736e-010
  1st-order autocorrelation coeff. for e: -0.024
  lagged differences: F(4, 197) = 1.763 [0.1379]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.848345
  test statistic: tau_ct(1) = -6.96881
  asymptotic p-value 3.06e-009
  1st-order autocorrelation coeff. for e: -0.024
  lagged differences: F(4, 196) = 1.887 [0.1143]
```

4.4 Cointegration Results – Long Term Model

After testing the stationarity of our variables, both dependent and independent, and realized that most of the variables except those of them containing rates are non-stationary in our long-term model, we must check our residuals from this model in order to be able and certify that the variables are cointegrated, they obey a long term relationship and they move in a way that can be expressed with the help of a linear equation.

In order to do the above mentioned processes we must run our linear regression firstly with the method of ordinary least squares, analyze it and from this model save the residuals in order to check them for unit root with the ADF test. If the residuals have no unit root that is they are stationary then the two variables are linked together with a linear combination.

Table 13: Long Run Model from 3/2001 - 5/2016

```
Model 4: OLS, using observations 2001:03-2016:05 (T = 183)
Dependent variable: l_EURODOLLAR
HAC standard errors, bandwidth 4 (Bartlett kernel)

                     coefficient   std. error   t-ratio    p-value
  ----------------------------------------------------------------
  const              -0.686613     0.386774     -1.775     0.0776    *
  l_NasdaqIndexEU     0.711918     0.0698129    10.20      1.68e-019 ***
  l_sp500            -0.546892     0.0950942    -5.751     3.82e-08  ***
  l_MiseryIndex       0.209538     0.0347746     6.026     9.53e-09  ***
  dif3monthrate       0.0318463    0.00593437    5.366     2.49e-07  ***
  germbondsrates     -0.117629     0.0199797    -5.887     1.93e-08  ***

Mean dependent var   0.212417   S.D. dependent var   0.139702
Sum squared resid    0.575633   S.E. of regression   0.057028
R-squared            0.837942   Adjusted R-squared   0.833364
F(5, 177)            85.74868   P-value(F)           1.98e-45
Log-likelihood       267.5363   Akaike criterion    -523.0727
Schwarz criterion   -503.8158   Hannan-Quinn        -515.2669
rho                  0.839574   Durbin-Watson        0.302233
```

Before starting to comment about the results of the Ordinary Least Squares method and our model we must check the residuals in order to certify that the variables are cointegrated, so we can proceed with further analysis. In order to do this we must check the stationarity of them and how they advance as a time series.

Below, the graph of the residuals is presented and we will analyze their stationarity with the help of the ADF test.

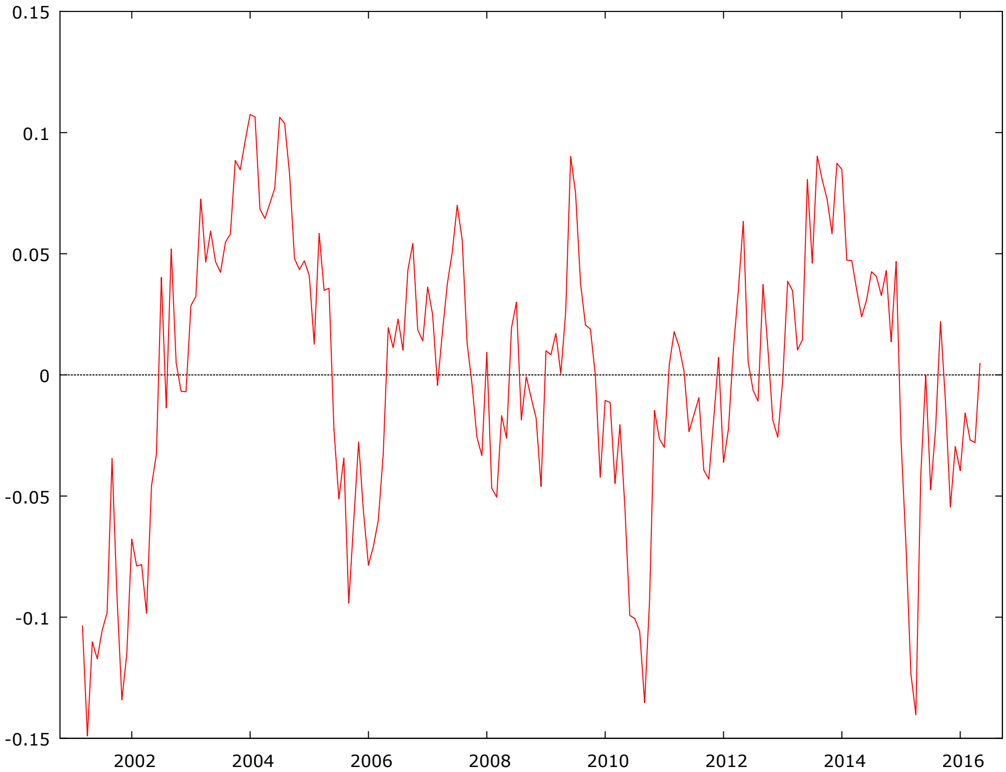

Figure 17: Residuals of our long term model

It is obvious from the figure above that the residuals have a white noise form as their mean seems to be close to zero and the variance stable, so proceeding with the ADF test we expect a stationarity.

Table 14: ADF Test for Residuals of our Long Term model

```
Augmented Dickey-Fuller test for uhat
including 0 lags of (1-L)uhat
(max was 13, criterion AIC)
sample size 182
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.160421
  test statistic: tau_c(1) = -4.09383
  p-value 0.001276
  1st-order autocorrelation coeff. for e: -0.042

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.159979
  test statistic: tau_ct(1) = -4.06571
  p-value 0.008393
  1st-order autocorrelation coeff. for e: -0.043
```

Investigating the table above and looking at the test with constant and trend we can confirm that our residuals are stationary and that there is no unit root since our p-value is 0.008393 and the tau_ct is -4.06 which is significantly below our critical price for the existence of unit root which is -3,90 so we can reject the unit root hypothesis with certainty.

Consequently, now we can further analyze our model since the variables are cointegrated. First of all, it is worth mentioning that we used the HAC standard errors methodology that manages to eliminate autocorrelation and heteroscedasticity in our model. Without this option we can conclude with significant standard deviation errors in our variables. On the other hand, we notice from the table above that all six std. errors in our variables are negligible.

In a linear estimating model like this the first characteristic to notice is its R^2. Consequently, we can be satisfied enough having a R^2 high scoring 0,837. Practically, according to this number, 83,7% of the real exchange rate from March 2001 until May 2016 can be justified from the variables we used, in other words from some macroeconomic and financial indices. The next thing to examine is the variables of our model, their statistical significance and whether their coefficients agree with the economic and financial theory. In the chapter 4.1 we thoroughly analyzed the roles of some of the most important factors that affect an exchange rate like the EUR/USD.

To begin with, Nasdaq Index for Eurozone coefficient is positive that is theoretically correct as a rise in this index can lead to an increase of our EUR/USD exchange rate and statistically significant as it has a p-value<1% so we can be assured that it is essential for our model. Moreover, sp500 coefficient index is negative which again agrees with the theory as it is an American stock market index based on the market capitalizations of 500 large companies having common stock listed on the NYSE or Nasdaq so an increase of the index may lead to a decrease of the EUR/USD exchange rate Its p-value is <1%, so we definitely know that the variable is important to our model. To continue, misery index for the USA has a positive coefficient as we were expecting considering that an increase of this index which contains the inflation rate and the unemployment rate in the USA may as well lead to an increase of the EUR/USD exchange rate. The variable is essential for our model too and we can notice this from its p-value which is well below <1%. Furthermore, the differential between the 3month interest rates of Euro and US Dollar is a factor affecting significantly the exchange rate and it has a p-value <1% too. The coefficient is positive as we were expecting that an increase in the Euro deposit interest rate will attract foreign funds to Eurozone, the demand for Euro will increase similar to exchange rate. In addition, we have, as a variable to our model, the 10year German bond rates and along with their statistical significance their coefficient is negative that is more than expected, as an increase in these rates (we used Germany as a benchmark for Eurozone) would be able to cause a decrease in our exchange rate, as insecurity about the German economy in the future usually leads to higher governmental bond rates, that could cause a decline in the EUR/USD exchange rate.

4.5 Error Correction Model – Short Term Model

We know from the econometric theory that if two, or more, variables are cointegrated, the relationship between them can be expressed as an ECM (Engle & Granger, 1987). With the help of the ECM we can combine the short run dynamics with the long run relationship using the error correction term that shows us the monthly adjustment in our exchange rate model and how "fast" our model approaches the real prices every month.

We now move from levels to differences to analyze the validity of our model, check if it can follow these changes in the short term which is in our case the monthly fluctuations of our exchange rate. Of course it is obvious that these adjustments are much more difficult in this case as we are studying the fluctuations of the dependent and independent variables and in the short term there are unpredictable factors that can affect the exchange rate such as the psychology of the investors or even some positive or negative shocks in the global economy.

Below there is a table and a figure of our model and how well it can fit the real, monthly, fluctuations of the EUR/USD exchange rate. Finally, we will comment on our residuals and the adjustments that are made every month in order to approach the real prices as well as the lag effect that is observed in one of our variables.

Table 15: Short Run Model from 5/2001 - 5/2016

Model 5: OLS, using observations 2001:05-2016:05 (T = 181)
Dependent variable: d_l_EURODOLLAR
HAC standard errors, bandwidth 4 (Bartlett kernel)

	coefficient	std. error	t-ratio	p-value	
uhat_1	-0.0662569	0.0219474	-3.019	0.0029	***
d_l_InportsUSA	0.364750	0.101757	3.585	0.0004	***
d_l_sp500	-0.220092	0.0548123	-4.015	8.83e-05	***
d_l_NasdaqIndexEU	0.258457	0.0413994	6.243	3.21e-09	***
d_l_NasdaqInde~_1	0.244688	0.0341895	7.157	2.25e-011	***
d_l_DowJones_1	-0.306078	0.0517708	-5.912	1.76e-08	***
d_germbondsrates	-0.0215585	0.0129251	-1.668	0.0971	*
d_l_EURODOLLAR_1	0.120009	0.0719773	1.667	0.0973	*

Mean dependent var	0.001309	S.D. dependent var	0.023923
Sum squared resid	0.051320	S.E. of regression	0.017223
R-squared	0.503305	Adjusted R-squared	0.483207
F(8, 173)	31.45124	P-value(F)	4.58e-30
Log-likelihood	482.3918	Akaike criterion	-948.7836
Schwarz criterion	-923.1956	Hannan-Quinn	-938.4096
rho	0.076971	Durbin's h	4.149233

First of all, we shall consider the R^2 of our model as well as the statistical significance of the variables we have used. Of course in the Error Correction Model we must pay thorough attention to our residual (uhat) its coefficient and its statistical significance too. Also, we have used HAC standard error methodology that manages to get rid of autocorrelation and homoscedasticity in our model.

To begin with, we have a R^2 scoring 50,33% that is satisfactory enough regarding to what has been already recorded in the literature review. Moreover, we can see from its p-value that our residuals from the long term model are statistically significant and its coefficient is -0.066. Negativity is really important for our econometric methodology and for purposes of dynamic stability in our model and the coefficient shows that every month the model "fixes" and reaches the actual prices for about 6,6 %. In addition, imports price index is important for our model too since its p-value is 0.0004 and the coefficient is positive showing us that, ceteris paribus, Euro will appreciate as long as the imports price index increases. Furthermore, SP500 and Dow Jones index are statistically important in our model according to their p-value, both variables have negative coefficient, as expected and an increase in these indices may lead to a depreciation of Euro against US dollar for the reasons that have been mentioned above. We shall not neglect to note that the variable Dow Jones is used with 1 period of time lag showing us that its past values affect the present values of the exchange rate. To continue, we have used the Nasdaq Index for Eurozone for our short term model as well both with time lag of 1 period and the present. After performing the test (table 16) we can conclude that these two variables are connected and there is a time lag effect between them and our exchange rate. In other words, both the past and the present value of this index affect the EUR/USD rate we are studying. One more variable that we have already used in the long term model is the 10year German bond rates. As we can see from the table of the regression it is statistically significant (the level of confidence is 10% for this variable) in the short term as well indicating that an increase and more precisely a positive change in the German bond rates may lead, ceteris paribus, to a depreciation of the Euro against the US dollar. Finally, we can see that the previous EUR/USD itself exchange rate affects as well the EUR/USD present exchange rate at about 12% with the level of confidence again at 10% for this variable.

Table 16: Test for Lag Effect for Nasdaq Index of Eurozone

```
Variables: d_l_NasdaqIndexEU d_l_NasdaqIndexEU_1
   Sum of coefficients = 0.503145
   Standard error = 0.053333
   t(173) = 9.43403 with p-value = 2.62929e-017
```

Below, we present the actual fluctuations of our exchange rate and the fitted ones produced by our short-term error correction model. Though, in most cases the predicted prices follow satisfactory the real ones and especially during the financial crises of 2008 we cannot be one hundred per cent satisfied as there are many factors that cannot be expressed in numbers and we have not included affecting the short-term flactuations.

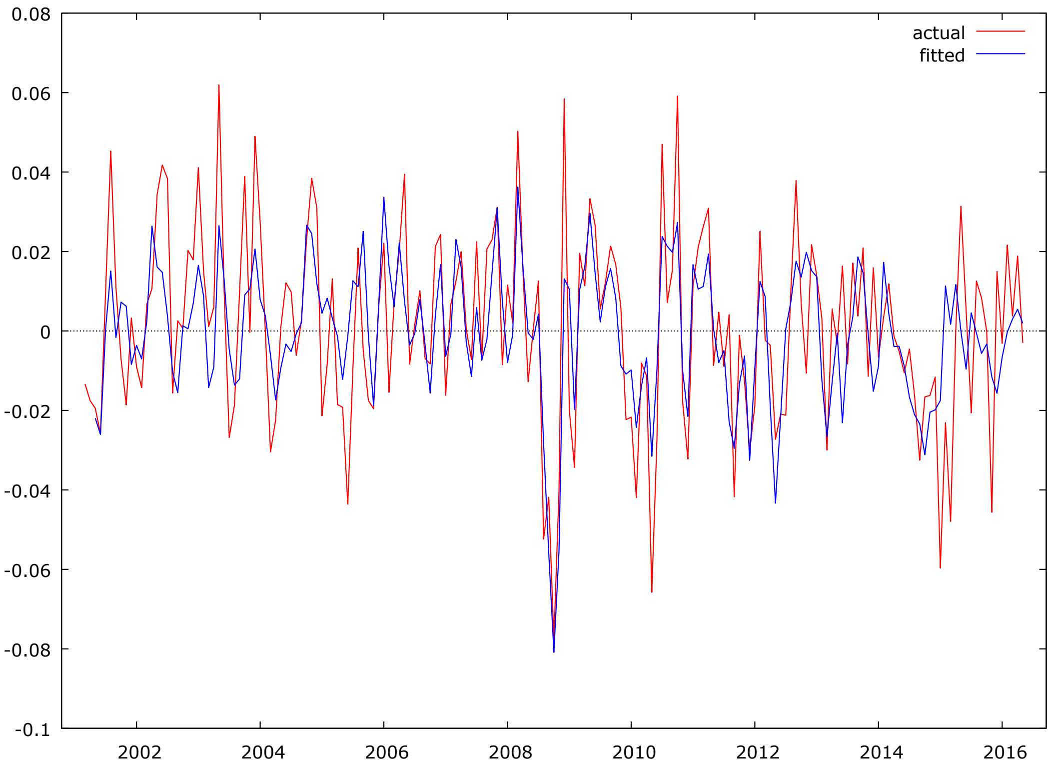

Figure 18: Actual and Fitted Short Term EUR/USD Time Series

4.6 Forecasts

The final part of our empirical analysis includes forecasts. We are testing our short term model from August 2008 until May 2016 in order to investigate its validity and reliability. Moreover, we will compare our short term error correction model with the random walk to investigate which one is more accurate.

As far as our model is concerned we derive the following results:

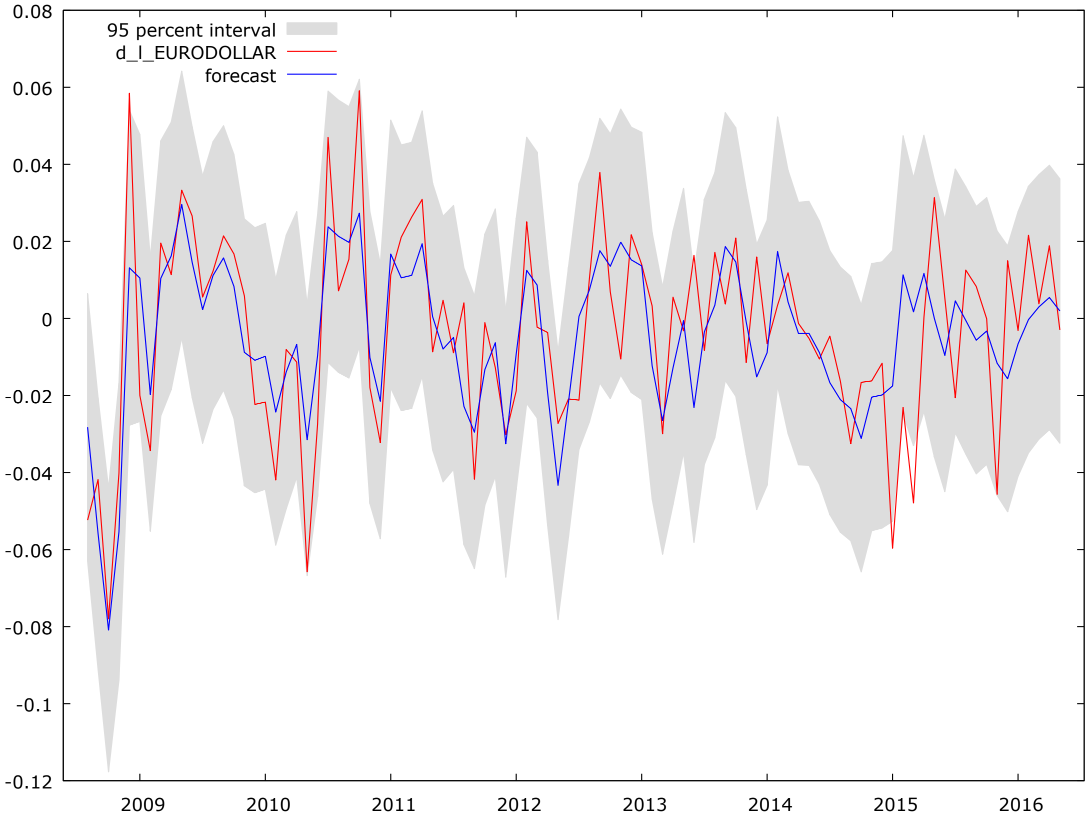

Figure 19: Forecasts for the Short Term Model

As we notice the forecast catches the trend of our exchange rate most of the times and some of its changes but, as expected, it cannot follow every fluctuation. Moreover, our error correction model does not follow the trend until the end in some cases and changes direction or changes its trend earlier or later than our EUR/USD exchange rate. As we have already mentioned above, predicting for the short term with great accuracy is really difficult because generally there are many factors that affect the exchange rate, some of which cannot be represented with indexes and some of which are really unpredictable. These factors usually refer to every day news (economic, political etc.) and psychology of the investors.

The following table contains the characteristics of our forecasts and shows us the quality of our predictions.

Table 17: Forecast Statistics of our model

Forecast evaluation statistics	
Mean Error	0.0010753
Root Mean Squared Error	0.017432
Mean Absolute Error	0.013612
Mean Percentage Error	-45.997
Mean Absolute Percentage Error	198.45
Theil's U	0.76123
Bias proportion, UM	0.0038052
Regression proportion, UR	0.0008388
Disturbance proportion, UD	0.99536

We will compare the result of our forecast evaluation statistics with the results that derive from the random walk theory that has been discussed a lot in the past literature for being the most suitable methodology to explain the short term fluctuations of exchange rates. In order to make this comparison we will run a linear regression of our first logarithmic difference of our exchange rate with a constant as the only regressor in order to analyze and comment the results.

After performing the Ordinary Least Square method we conclude to the following results.

Table 18: Forecast Statistics of random walk for the same period

Forecast evaluation statistics	
Mean Error	-0.0045259
Root Mean Squared Error	0.025424
Mean Absolute Error	0.019548
Mean Percentage Error	109.07
Mean Absolute Percentage Error	114.97
Theil's U	1.0229
Bias proportion, UM	0.03169
Regression proportion, UR	2.9115e-033
Disturbance proportion, UD	0.96831

Comparing the characteristics of the two different forecasts we can claim with certainty that our model beats the random walk. First of all, the Root Mean Squared Error in the first case of our model is 0.017432 which is significantly less that the RMSE of random walk which is 0.025424. Moreover, the Mean Error in our model is 0.0010753 that is better than the Mean Error of random walk's that is -0.0045259. Finally, Theil's U a relative accuracy measure is lower in the former model scoring 0.76 rather than in the latter that is 1.022. It is known that the lesser this index is the better the model for predictions.

To conclude, we present the figure of the forecasts of random walk for the period from August 2008 until May 2016. As it can be clearly seen, not only random walk is not functional but also in many cases the prices of EUR/USD in the short term and the fluctuations are outside the shaded area which is the 95% confidence interval comparing to figure 19 where as we can see this does not apply.

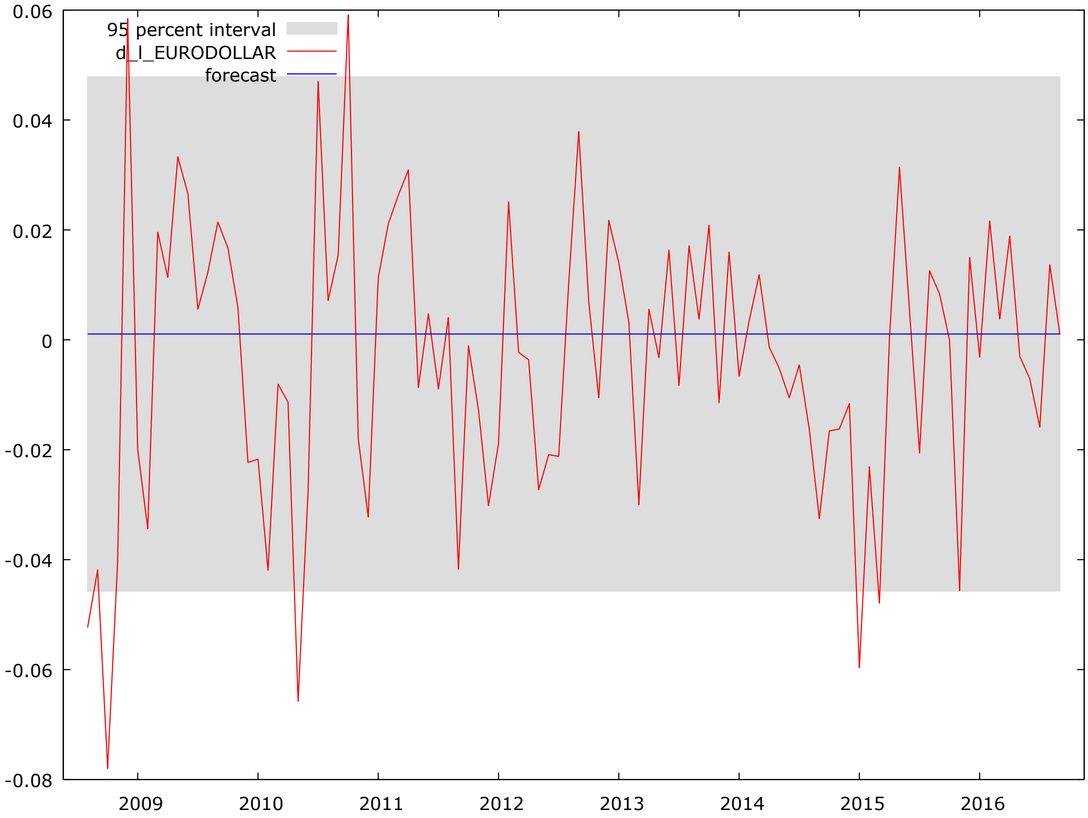

Figure 20: Forecasts according to random walk for the same period

5 Conclusions

To conclude, we can sum up with the major points of this research. We studied and thoroughly analyzed the exchange rate of EUR/USD for the period of March 2001 until May 2016. The specific exchange rate is of great importance not only for investors but also for traders, managers and merchants. We divided our sample into two periods, the first one from March 2001 to July 2008 and the second from August 2008 to May 2016, in order to perform some forecasts for the latter period.

From a short review of the empirical literature we noticed that there is a great number of papers that use various models (linear and non-linear) and methodologies to explain exchange rate movements. Precisely, a part of them have used theoretical models and another part more applied ones with variables chosen following the econometric theory in both cases.

Collecting the monthly time series data of the EUR/USD exchange rate was the first step of this research. Afterwards, we studied theoretically the factors that affect generally the forex market and more specifically this complicated exchange rate. After testing many variables with the Ordinary Least Squared method we came to a rather satisfactory result according to the grade that our variables can explain the exchange rate. We would not have proceeded with the research if the independent variable (the exchange rate) and the dependent (our regressors) had not been cointegrated since nearly none of them were stationary, except from the residuals of the model that helped us to reach the above conclusion, so the t-student distribution and the classic econometric analysis would not be useful. Their stationarity is tested with the ADF Test for unit roots. According to the theory, two cointegrated variables can be expressed with the help of the error correction model (with the help of the error term) and from the long run model we move to the short run model where instead of having the logarithms of our variables (we made this transformation for scaling purposes) and their levels, we now have the first differences of them as at this point of our project we are interested in the monthly changes and fluctuations of the exchange rate. Both the long-run and the short-run model are decent and their results truly agree with the already known theory, managing to explain in a significant degree the evolution of the EUR/USD time series for this period.

Finally, we performed forecasts for the second period of our sample in order to test our model with satisfactory results and far better than the ones derived from the random walk model/theory. Obviously, there is always room for further improvement but the enhancement of the above models is quite difficult at this point since there are unexplained factors that can affect the EUR/USD time series as well as other that can be explained but cannot be easily expressed in a mathematical form.

6 References

Baer, D., 2015. *Business Insider.* [Online]
Available at: http://www.businessinsider.com/history-of-the-dollar-2015-2
[Accessed 2017].

Christian Dunis, M. W., 2002. *Modelling and Trading the EUR/USD Exchange Rate: Do Neural Network Models Perform Better?,* s.l.: Liverpool Business School and CIBEF.

David Dickey, W. F., 1979. Distribution of the Estimators for Autoregressive Time Series With A Unit Root. *Journal of the American Statistical Association* .

Domenico Sartore, L. T. ,. M. T. &. F. V., 2002. US dollar/Euro exchange rate: a monthly econometric model for forecasting. *The European Journal of Finance.*

Domenico Sartore, L. T. M. T. F. V., 2003. Euro/Dollar Exchange Rates: A multi-country structural monthly econometric model for forecasting. *Greta.*

ECB, 2017. *European Central Bank.* [Online]
Available at:
https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html
[Accessed March 2017].

Engle, R. F. & Granger, C. W. J., 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*.

Ghalayini, L., 2014. Modeling and Forecasting the US Dollar/Euro Exchange Rate. *International Journal of Economics and Finance.*

Guillaume Weisang, Y. A., 2008. *Vagaries of the Euro: an Introduction to ARIMA Modeling,* s.l.: s.n.

Gujarati, 2004. *Basic Econometrics.* 4th ed. s.l.:The McGraw Hill Companies.

Halls-Moore, M., 2014. *www.quantstart.com.* [Online]
Available at: https://www.quantstart.com/articles/Basics-of-Statistical-Mean-Reversion-Testing-Part-II
[Accessed 2017].

Iordanova, T., 2007. *www.investopedia.com.* [Online]
Available at: http://www.investopedia.com/articles/trading/07/stationary.asp

Jamaleh, A., 2002. Explaining and forecasting the Euro/Dollar exchange rate through a non-linear threshold model. *The European Journal of Finance.*

Karfakis, C., 2007. Is there an empirical link between the dollar price of the euro and the monetary fundamentals?. *Applied Financial Economics.*

MacKinnon, 1996. Numerical Distribution Functions for Unit Root and Cointegration Tests. *Journal of Applied Econometrics*.

Paul De Grauwe, 2000. *Exchange rates in search of fundamentals , the case of the Euro-Dollar rate,* s.l.: University of Leuven and CEPR.

Schnatz, J. C. B., 2000. *The determinants of Eurodollar exchange rate, synthetic fundamentals and non existing currency,* s.l.: Economic Research Group of the Deutsche Bundesbank.

Telegraph Media Group, 2010. *http://www.telegraph.co.uk/.* [Online]
Available at: http://www.telegraph.co.uk/finance/markets/8170326/Timeline-history-of-the-euro.html
[Accessed 2017].

The Editors of Encyclopedia Britannica, 2007. *https://www.britannica.com.* [Online]
Available at: https://www.britannica.com/event/Maastricht-Treaty
[Accessed 2017].

Thomas, L., 2011. *Forecasting of Exchange Rates: A case study for the Eurodollar,* s.l.: University of Macedonia.

Wenhao, L., 2004. *Currency competition between Euro and US Dollar,* s.l.: Business Institute Berlin at the Berlin School of Economics.