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Oil Prices and Inflationary Pressures in the Eurozone

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Introduction

One of the main goals of the European Central Bank (ECB) is to maintain an inflation level of about 2% in the Eurozone. Inflation levels have been declining since Q4 2011 in the Euro area and have been below the 2% threshold since Q1 2013 (European Central Bank, 2016). In order to combat these low inflation levels, the ECB has been implementing policies of lowering refinancing interest rates and quantitative easing. As of March 2016 the refinancing interest rate sits at 0.00%. The ECB has been lowering its refinancing rate regularly since July 2012 to rejuvenate the big economies in the Eurozone and increase their inflation levels at the same (European Central Bank, 2016a). So far it has not been proven to be successful. The ECB expanded their efforts in the last few years by implementing quantitative easing; buying bonds with printed money (The Economist, 2016).

Nowadays, May 2016, the Euro area is still in a state of moderate economic growth and low inflation. This is an undesirable situation for the ECB and the Eurozone as the instruments of monetary policy are not working optimally. The refinancing rate is already at an all-time low and lowering the refinancing rate to a negative value has serious implications (The Economist, 2016).

The lack of impact of monetary policy may be caused by the recent oil shock that has been present for one and a half years now. The continuous decline of oil prices in the past 18 months might undermine the expansionary policy. The recent oil shock originated mostly out of increases in supply in the Middle East. Also the emergence of alternative energy resources contributes to the fact that oil prices have been decreasing (The Economist, 2016a).

Oil is still a major commodity in the Eurozone (and the world), disturbances in the price level of oil could have a significant impact on overall price levels in all of Europe. This thesis will try to assess whether oil prices have a significant impact on inflation levels and inflation expectations. If so then low oil prices might undermine ECB's policy to stabilize inflation alongside other factors that will be discussed in the thesis. The aim for this thesis is therefore to answer the following question:

Do low world oil prices undermine ECB's monetary policy, to stabilize inflation, by creating a downward pressure on inflation and inflation expectations?

This is an economically and academically relevant question as this phenomenon is quite uncommon and thus not researched thoroughly. Most literature on the subject of oil prices and inflation is based on large increases in oil prices rather than sharp declines(Leblanc & Chinn, 2004)(Blanchard & Riggi, 2013)(Badel & McGillicuddy, 2015). Therefore it is also challenging and relevant to find out if the effects of a continuous decline produce opposite but intuitive results or if they produce counterintuitive results. It is intuitively expected, given declining oil prices, that inflation and inflation expectations will decline as well (ceteris paribus). Thus implying a positive relationship between oil prices and inflation and inflation expectations.

The thesis is structured accordingly to the academic standards. The theoretical framework follows after the introduction where a literature review and hypothesises are present. Thereafter, data and methodology are demonstrated followed by the results. To conclude, a conclusion is constructed alongside a discussion section.

This research found evidence on a significant effect of oil prices on inflation expectations and inflation in terms of Consumer Price Index (CPI). However, there was no evidence found of such an effect on inflation in terms of core CPI which excludes price fluctuations in energy, food, tobacco and alcohol related goods.

Literature review

One of the ECB's main objectives is to maintain a stable inflation level throughout the whole Eurozone. By adjusting refinancing rates and increasing or decreasing the money supply the ECB tries to target an inflation level of 2% (European Central Bank, 2016). This is commonly known as inflation targeting which is an important objective of most central banks in the world.

Controlling inflation levels has proven to be a daunting task for central banks as inflation can be highly volatile due to changing expectations. Inflation expectations are a major factor that a central bank should consider when implementing monetary policy. The importance of inflation expectations has been researched thoroughly both theoretically and empirically. The short term augmented Phillips curve and the NKPC (New Keynesian Phillips curve) are major contributions in this field of research. The mechanics behind the Phillips curve are straightforward and describe a trade-off between the output gap (or unemployment) and inflation. As unemployment rises inflation declines implying a trade-off between the two variables. The augmented Phillips curve adds that economic agents alter their inflation expectations accordingly to changes in monetary policy. The equation of the short term augmented Phillips curve can thus be defined as follows: $\pi = \pi^e - \varepsilon(U - U^*)$ where π represents inflation and π^e represents the inflation expectations. The augmented Phillips curve thus implies that inflation expectations influence inflation. Consumers and firms alter their expectations according to changes in fiscal and monetary policy, for example. They anticipate a rise in inflation if the government implements expansionary fiscal policies. Additionally, ε determines the sensitivity of inflation on deviations of U (actual output) in contrast to U* (potential output) (Friedman, 1977). The NKPC adds that due to sticky prices expectations can alter unemployment and inflation temporarily but not permanently. Moreover, NKPC places great importance on real marginal cost as a driver of inflation instead of the output gap used in Phillips curve analysis (Clarida, Gali, & Gertler, 1999).

Most research related to this thesis' subject makes use of regressions based on the augmented Phillips curve and NKPC. Hooker (2002) wrote an article about the plausibility of inflationary pressure when oil shocks occur. Oil price fluctuations have been widely considered as a major factor influencing inflation as it constitutes a large part of the CPI basket of goods. Furthermore, oil being a commodity that is widely used throughout many production processes implies that shocks in oil prices can significantly impact inflation levels (Montoro, 2010).

Hooker examines the proposition that oil shocks plausibly cause inflationary pressure with Phillips curve models that account for nonlinearities and breaks. Measuring the impact of oil prices in a time series setting has proven to be quite difficult. In the timeframe 1960-2000 oil prices tended to be relatively stable for most of time but could change abruptly due to shocks. In his analysis he found that oil prices had significant impact on core inflation pre-1980. Post-1980 the impact of oil price fluctuations eroded to a point where oil price fluctuations were only marginally significant. Hooker mentions that this break is likely caused by impactful changes on the energy market, specifically less energy intensity and deregulation of the market. However, statistical evidence could not be found in this analysis to support these claims. Hooker concludes that Taylor (2000) examined a compelling reason stating that a monetary regime change caused the lowered impact of oil price fluctuations.

The link between oil prices and inflation expectations has been of interest for a few decades now ever since the oil shock in the 1970's where rapidly increasing oil prices caused high inflation by altered inflation expectations. Thus possibly implying a positive relationship between the two factors. O'Neill, Penm and Terrell (2008) published an article on the relationship between high oil prices and inflation expectations in the major OECD countries. They examined data on both factors over a time period of 4 years (2003-2006). Initially when oil prices were rising in 2003 and 2004, inflation expectations were following a similar pattern. Compared to the 1970's and 1980's inflation expectations are less prone to the pressure of rising oil prices, meaning that inflation levels were significantly higher when oil prices rose. Eventually, high inflation expectations slowed down while oil prices were still rising. According to O'Neill, Penm and Terrell (2008) this implies that there is no long term relationship between oil prices and inflation expectations. They concluded that a clear relationship is only visible in the short run, differences between the countries alike.

Referring back to the statement that inflation expectations nowadays seem to be less prone to the pressure of fluctuations in oil prices, Blanchard and Riggi (2013) published an article on this plausible development in the USA. They found that large increases in oil prices in the 2000's are not followed by proportional changes in inflation compared to the

1970's and 1980's. This is remarkable considering that the fluctuations in oil prices have been relatively higher than in the 1970's and 1980's.

They mention three factors that might have lowered the inflationary pressure of oil shocks; less dependence on oil in today's economies, improvements in monetary policy and less wage rigidity. They concluded that wage rigidity significantly decreased and monetary policy has become more credible and is more able to manage inflation expectations.

An article published on the effects of oil prices on inflation in the G-5 countries (U.S.A., Japan, United Kingdom, France and Germany) provides insights that are particularly applicable to this thesis. It is also based on a Phillips curve approach like most research on this subject. Analysis is set in a time frame that stretches from 1980 until 2001 with the 1980's being volatile and the 1990's being quite stable in terms of inflation. Differences in inflation levels across countries is mostly caused by differences in oil intensity of production and Europe having powerful labour unions. Europe tends to be more sensitive to oil price fluctuations due to labour unions negotiating higher wages when oil prices rise. Furthermore, competition is less fierce in Europe leading to producers compensating fluctuating oil prices by letting the consumers pay the price. Leblanc and Chinn (2004) constructed a short run Phillips curve regression model describing the trade-off between inflation and unemployment. Included endogenous variables in the regression model are crude oil prices and the refinancing rate to account for monetary policy to some degree. The effective exchange rate is taken as an exogenous variable to relax the assumption that the refinancing rate is the sole variable for conducted policy. All endogenous variables included have 4 lags. Concluding their analysis, Leblanc and Chinn state that oil price fluctuations have modest impact on inflation levels in all mentioned countries. They estimated that a 10% increase in oil prices lead to increases in inflation levels of about 0.1-0.8% (Leblanc & Chinn, 2004). Notably, the impact of oil price fluctuations also seems to be diminishing in this timeframe. Leblanc and Chinn mention that oil intensity in production decreased in the US and labour unions lost regulatory power in Europe.

Data

Robust empirical analysis relies on good use of statistical methods and reliable and precise data. Drawing conclusions out of faulty data or wrongly estimated coefficients make statements seem not representative or not academically sound.

Data concerning this type of research is available through the Bloomberg financial database and the ECB statistical data warehouse. Data on the variables 5Y5Y Inflation swap rate, CPI, Core CPI, real effective exchange rate and Brent oil prices were gathered via the Bloomberg financial database. The ECB statistical data warehouse provided data on their Asset Purchase Programmes (APP) and the interest rates namely the 12 month money market interest rate and the bank interest rate for household loans with a maturity of no more than a year. Bloomberg is widely considered as the standard for financial databases as it provides reliable data on many aspects of economics. The ECB can also be considered to be a reliable source of data as it is one of the most important financial institutions in the EU. All data variables mentioned above are gathered for the Eurozone as a whole. The Eurozone consists of 19 members total.

The analysis on inflation and inflation expectations in relation to oil prices spans over the last ten years, that is from January 2005 until May 2016. This time frame has some interesting aspects as it contains the 2008 financial crisis and the dramatic drop in oil prices since Q3 2014. Data on this frame is gathered on a monthly basis to obtain a total amount of 137 data points per variable. All data is linked with their respective month and year which makes a smooth transition into the statistical software possible.

The dependent variables in this research, inflation and inflation expectations, can be measured in a couple of methods. Three methods will be discussed and set as dependent variables for the regression models. One of these methods is to take the difference between the yield of nominal bonds and inflation linked bonds. This concept of measuring inflation expectations is a direct derivation of the Fisher equation. The Fisher equation ($R = r + \pi^e$) implies that the real interest rate is an enumeration of the nominal interest rate and the inflation expectations. Given R and r, inflation expectations can be calculated. The 5 year 5 year inflation swap rate is taken here as a variable for inflation expectations. This variable contains the expected inflation over 5 years, 5 years from now. Hence, 5Y5Y inflation swap rate. This is a reasonable variable to look at when measuring inflation expectations as it indicates what investors expect given central bank or government policy. The ECB is especially interested in this variable as it is trying to bump up inflation to avoid the highly risky prospect of deflation. The inflation swap rate can give the ECB an indication on the effects of their policies on market expectations. The swap rate has its drawbacks as a variable for determining inflation expectations. It is a financial market based variable implying that the swap rate is also under the influence of risks that are not related to factors influencing inflation. Liquidity risk in particular can interfere with the reliability of the swap rate as variable for inflation expectations. The 5Y5Y inflation swap rate is also, as the name suggests, a long term variable that does not account as much for short term deviations as other methods like inflation expectation surveys.

Current inflation indexes like the CPI and core CPI are also analysed in this thesis as these capture the immediate effect of oil price fluctuations on inflation. CPI stands for Consumer Price Index, this index measures the percentage change in overall price of a basket of goods. The share of consumption of these goods in the basket determine the weight of a group of goods. Energy prices form a major share in the CPI basket and oil prices are a large contributor to energy prices. Therefore core CPI is an useful measure to capture inflation excluding the impact of oil price fluctuations. Core CPI uses the same approach as the regular CPI but core CPI excludes energy, food, tobacco and alcohol related goods. Core CPI might be affected by second round effects of oil price fluctuations. Core CPI may not be directly affected by oil price fluctuations as they are not included in the core CPI basket. It could take time for oil price fluctuations to be fully reflected in production costs and prices of goods that are included in the core CPI basket. The ECB names its measure for CPI and core CPI Harmonised Index for Consumer Prices (HICP).

These three measures of inflation and/or inflation expectations are being analysed separately as I suspect differences in response to oil price fluctuations. CPI is expected to be the most sensitive to oil price fluctuations. The CPI basket contains about 20% of energy prices and thus oil price fluctuations should directly affect CPI. CPI (and core CPI) is also a short term variable compared to the 5Y5Y swap rate and thus CPI (and core CPI) is expected to react more abruptly to changes in macro-economic conditions. Core CPI excludes oil price fluctuations in its calculation, therefore oil price fluctuations seem not to be directly affected by oil price fluctuations. However, core CPI may be prone to second round effects mentioned in the previous paragraph. Inflation expectations, in terms of the 5Y5Y rate, are expected to react instantly to changing macro-economic conditions and oil price fluctuations. The swap rate is a market based metric and financial markets are characterised by their quick response to any changes in macro-economic conditions and fluctuations in for example oil prices. In contrast to CPI and core CPI, the 5Y5Y inflation swap rate is a long term variable. It should react less abruptly to before mentioned changes and fluctuations.

The dependent variable, inflation and inflation expectations, consists of an index that is either CPI, core CPI or the 5Y5Y inflation swap rate (figure 1). Calculations of the percentage change in these indices are already provided by Bloomberg thus calculation of any sort is not needed for the dependent variable.

Crude oil price is the independent variable and the coefficient that this research is trying to estimate. The most widely used and most applicable measure for oil price fluctuations is the Brent crude oil price (figure 2). The Brent is most applicable representation for the crude oil price in the Eurozone because the Brent is the price index for petroleum produced in the Middle East, Europe and Africa flowing west. The logarithmic difference approximately captures the required measure for the independent variable, percentage change in oil prices respectively. The percentage change in Brent crude oil prices is thus calculated as follows:

$$\%\Delta \text{ Brent} = Log(Brent(t)) - Log(Brent(t-i))$$

Where t represents the current month and i represents the amount of months dating back from the current month. The annual logarithmic difference will be taken for the percentage change in oil prices to match inflation and inflation expectations. Inflation and inflation expectations are mostly indices for annual price changes instead of monthly changes. It also provides more stable data then monthly changes.

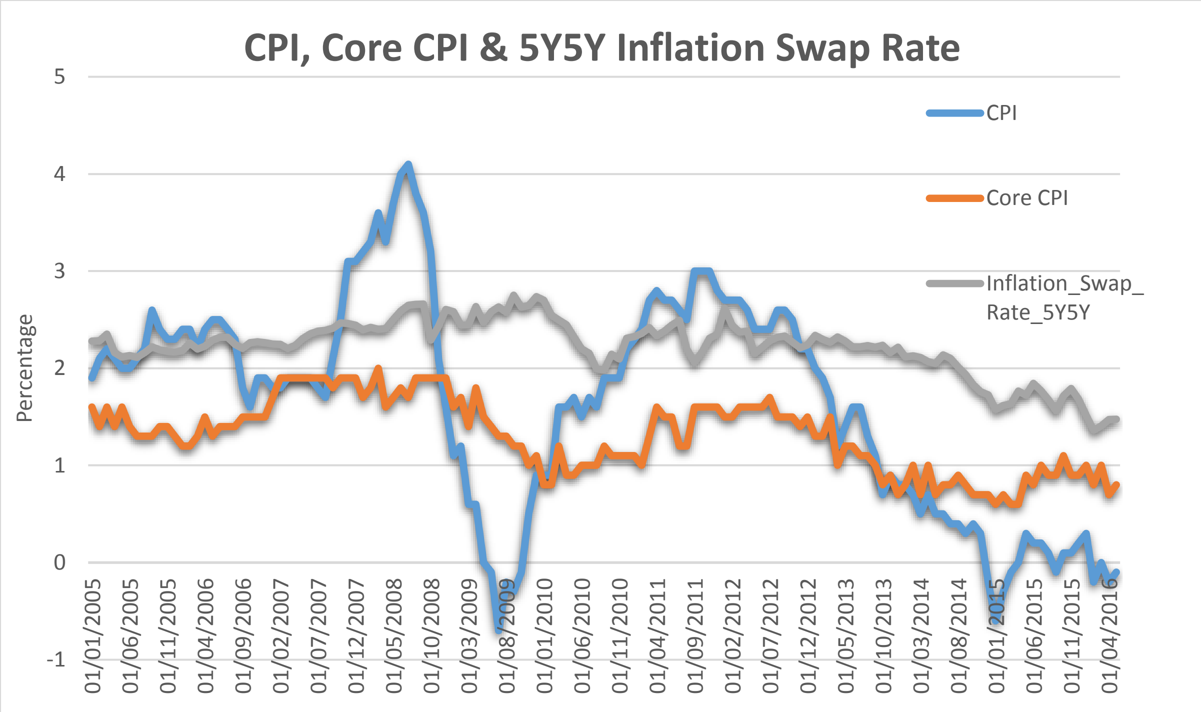

Figure 1: CPI, Core CPI and 5Y5Y Inflation Swap Rate

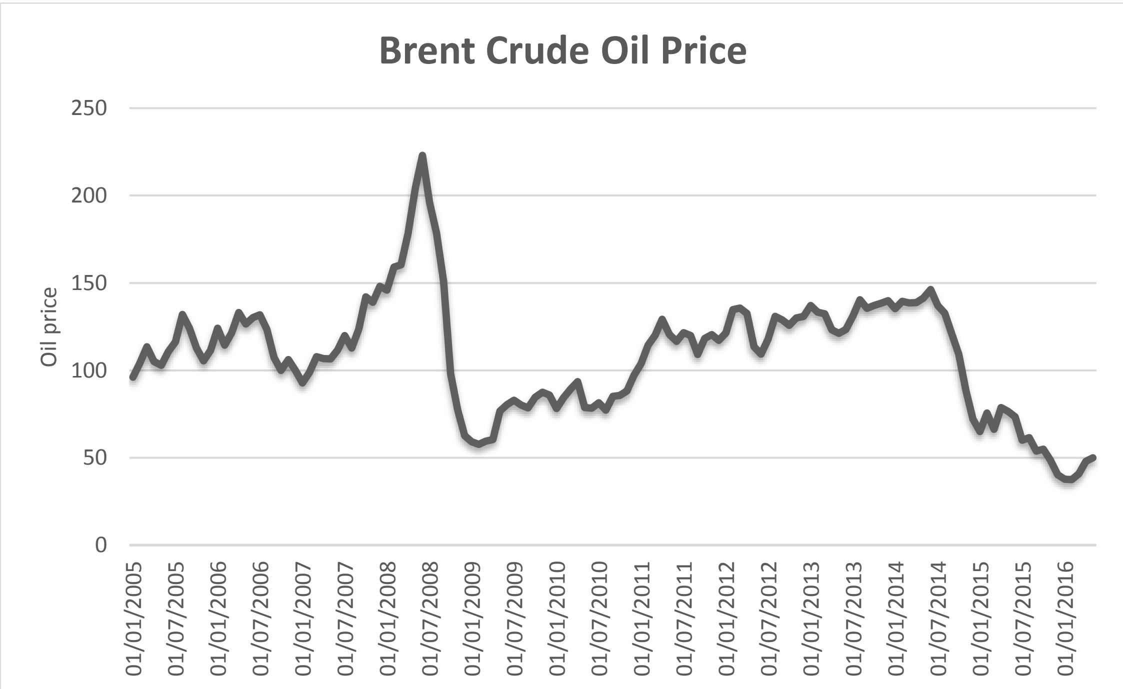

Figure 2: Brent Crude Oil Price

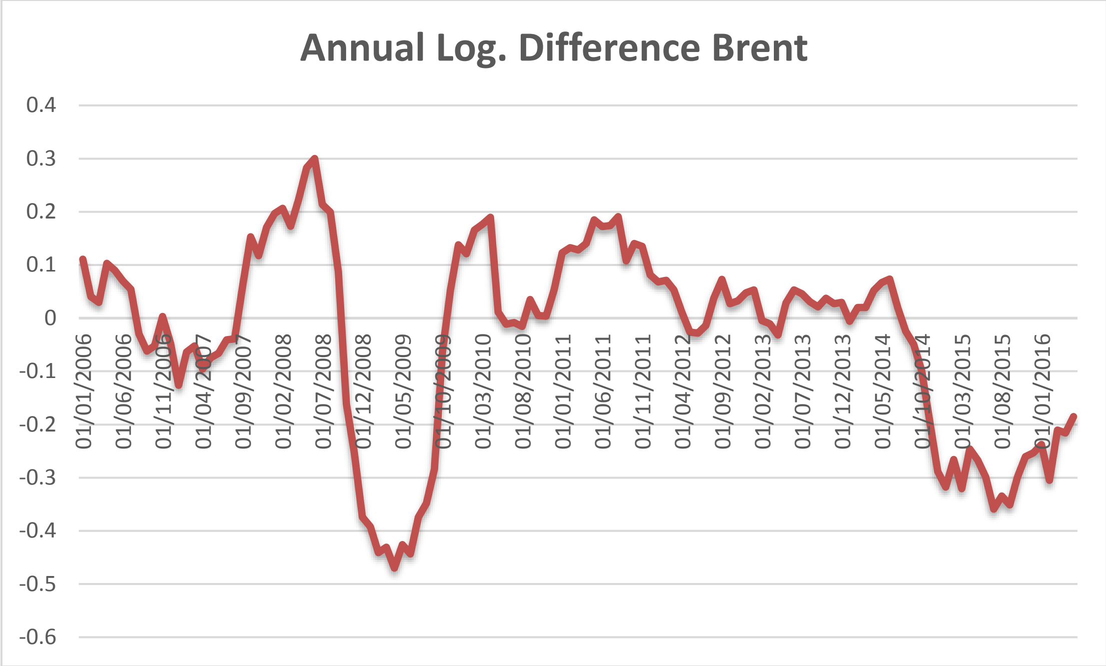

Figure 3: Annual Logarithmic Difference Brent

At first sight it is visible that core CPI and the 5Y5Y swap rate seem to follow the same trend throughout the time frame. However, CPI seems to be much more volatile and sensitive to changing macro-economic conditions. Not surprisingly considering that CPI is a short term variable and oil price fluctuations are incorporated into CPI. It is logical that CPI reacts more abruptly to changing macro-economic conditions. The swap rate is a long term expectation of inflation that is not affected as much by short term fluctuations. Core CPI excludes oil price fluctuations and thus does not react as abruptly to said fluctuations in the short term.

Several control variables are to be considered when it comes to estimating the effects of oil prices on inflation (expectations). Inflation is an economic variable that is influenced by a lot of factors. Ignoring these factors in the analysis could lead to spurious regression. I looked at the traditional and commonly known factors influencing inflation (expectations). The output gap and/or unemployment as in the short term augmented Phillips curve ($\pi = \pi^e - \varepsilon(U - U^*)$) and the NKPC (real marginal cost) should definitely be considered. As stated in the theoretical framework, The output gap and/or unemployment levels are expected to have a negative relationship with inflation and inflation expectations. If unemployment is declining than inflation is expected to rise. Unfortunately most data on these factors is not available on a monthly basis except for unemployment rates/levels. Unemployment rates and levels do, however, not fit the data at all. The output gap, in general, is quite hard to implement in a model as well. First of all, GDP (U) follows an upwards trend in most countries where economic growth is present. Secondly, GDP is seasonal and thus must be adjusted accordingly to avoid faulty regression.

Interest rates are also interesting to look at. If interest rates rise, the costs of holding and borrowing money increases. Consequently inflation is expected to decline due to lower demand of money. I have looked at current levels of the 12 month money market interest rate in the Eurozone.

The ECB has been expanding their asset purchase programmes in the last few months as mentioned in the introduction. These asset purchase programmes (APP) increase the money supply in terms of M3, not M1 necessarily. Still, it can be assumed that the money from the asset purchase programmes will flow from M3 toward M1. Therefore, an increase in the volume of these APP's should increase M1. The money flowing from the APP's to M1 increases the disposable income of households. The increase in disposable income induces households to consume more and thus demand increases. Without a supply adjustment, prices will increase and thus inflation as well. In terms of data I looked at the annual percentage changes (Log difference) in the ECB's Main Refinancing Operations (MRO) volumes.

The effective exchange rate measures the overall strength/valuation of a currency. If the euro, for example, has a declining effective exchange rate then the euro's value is relatively declining in comparison with other currencies. In terms of the relationship with inflation (expectations) there is supposed to be a negative relationship. If the real effective exchange rate of the euro is worsening then it exports will rise because of the cheaper currency. Imports decrease as it becomes more expensive to import goods and services out of other countries. Increasing exports and decreasing imports increases domestic demand, without a supply adjustment prices increase and hence inflation increases. As for data, I looked at the real effective exchange rate index to prevent omitted variable bias (OVB). The real effective exchange rate applies a correction for inflation that helps preventing OVB in the regression model.

Variables like interest rates and exchange rates can be quite volatile due to their quick adaptation to changing market conditions. Putting these variables in the model as they are in raw data can disturb the regression model. By applying the moving average method to these specific variables we can smooth out the rough fluctuations and create better visible trends or cycles in the data and graphs. In this analysis the moving average has been applied up to a 3 month basis, not longer. The real effective exchange rate is taken as a 3 month moving average to account for excessive volatility between months.

Methodology

The main goal of this thesis is to assess whether oil prices positively affect inflation and inflation expectations. This will be done empirically. In order to estimate the effects of oil prices on inflation and inflation expectations in the Eurozone the Ordinary Least Squares (OLS) method of regression will be used. OLS is a standard method for estimating a plausible relation between two variables. As long as the assumptions of OLS are satisfied then OLS can produce a reasonable estimate. The assumptions being that the expected value of the error term is equal to zero, homoskedastic standard errors and the independent variables are not collinear. In a time series regression model there is a chance of having auto correlation, auto correlation leads to unreliable and biased estimates of the coefficients. In order to test whether auto correlation is present we use the Durbin-Watson statistic(d). The Durbin-Watson statistic tests if the errors are serially uncorrelated or not. The statistic (d) ranges from 0 to 4 where d=2 represent a model with no auto correlation. So we are looking for values of d that are relatively close to d=2. When d gets smaller than 1 or larger than 3, then auto correlation is likely to be present. In order to correct for auto correlation in a model we can implement a lagged dependent variable (LDV). By implementing a LDV we can assume that the independent variables are independent of the previous value of the dependent variable. If a LDV is needed then a basic Auto Regressive (AR) (appendix B) model will be constructed in order to compare the AR model with baseline model with the independent variable. This allows me to assess whether the independent variable (oil prices) have added value in terms of R-squared and the adjusted R-squared.

The Breusch-Godfrey test for serial correlation allows us to test whether serial correlation is still present in the final model with the LDV included. Firstly, the Q-statistic correlogram will be analysed to determine in which lag(s) serial correlation might still be present (appendix C). The Q-statistic in this setting determines whether a group of auto correlations are not equal to zero (Ljung-Box test), based on the significance we can see if a residual lag is serially correlated or not. In this case twelve lags will be analysed in the correlogram meaning that the lags of the residuals will be analysed up to the twelfth month prior to the initial month. Based on the results in the correlogram a Breusch-Godfrey test for serial correlation will be performed for the order of lags that might be serially correlated.

Assessing whether the model has a good fit will be done with measures of goodness of fit like the overall significance of the model (F-statistic), R-squared and the adjusted R-squared. R-squared determines to what extent the model explains the variance in the dependent variable. Adding multiple variables into a model will always increase R-squared but doing that does not necessarily result in a better model. The adjusted R-squared accounts for the number of variables used in the model and thus gives us a better indication of the most optimal model. Moreover, analysing the actual and fitted residual graph will give some insight into what extent the model fits the reality. Additionally, in order to correct for plausible heteroskedasticity consistent standard errors the Newey-West covariance estimator will be implemented. This will account for the highly likely heteroskedasticity present in the dataset due to several changing macroeconomic conditions (as shown in the residual graphs in the results section).

The analysis will consist of three parts where inflation expectations (5Y5Y inflation swap rate), CPI and core CPI are being analysed separately. The dependent variables are all separately modelled with the same set of independent and control variables available to them. Additionally, the three dependent variables will be modelled in three stages starting from a baseline model.

At first a baseline model is constructed where only the inflation index and the Brent oil price are included. This will give an initial indication of how and to what extent the two variables are related. Inflation and inflation expectations has, as mentioned before, a lot of variables that might have significant influence on inflation. Thus it is likely that the regression model is prone to omitted variable bias (OVB). In order to somewhat minimize OVB I have included control variables that are reasonable and fit in the model. Estimates of the effects of oil price fluctuations on inflation and inflation expectations should be more accurate as a result of implementing these control variables. In stage two we expand the model with the control variables mentioned in the data section namely: household interest rate, real effective exchange rate and the ECB refinance operations volumes. Adding these control variables should eliminate some of the omitted variable bias.

The last stage of modelling consists of adding dummy variables for any significant disturbances in the data. Dummy variables can be appropriate in this analysis where irregularities in data can be separated from the regular and stable data. Examples of irregularities in this data set can include events like the 2008 financial crisis, the 2010 European debt crisis or the more recent negative oil shock. Looking at the data and its accompanying graphs (figure 1,2) there is a clear visual disturbance in the years of 2008 and 2009 where oil prices first rose dramatically and then dropped rapidly after. There seems to be a break in the assumed relationship in 2008-2009 between oil prices and the 5Y5Y inflation swap rate, core CPI. Core CPI and the swap rate seem to not react as accordingly to the 2008-2009 financial as CPI. The difference is likely caused by the fact oil price fluctuations are directly reflected in the basket of CPI goods where energy prices are included. Core CPI will likely not be directly affected by oil price fluctuations, but it might be prone to the second round effects. The second round effects take place later and are also expected to have a weaker influence on core CPI, thus a break in the relationship is to be expected in the 2008-2009 time frame. The swap rate does react instantaneously to oil price fluctuations due it being a market based metric. However, the swap rate is a long term expectation of inflation and thus short term oil price fluctuations are expected to have a weakened impact compared to CPI. The swap rate is also likely to have a break in the relationship with oil prices. Therefore a dummy variable for core CPI and the swap rate will be implemented for this particular time frame.

The baseline model shows the initial estimate of the relationship between inflation, inflation expectations and oil prices. The amount of lags included depends on the significance of said lags. Lags may be included due to a delayed impact of oil price fluctuations on changes in CPI and core CPI. Formally noted as follows:

$$\text{Inflation rate} = \beta_0 * \text{Constant} + \beta_1 * \%\Delta\ \text{Brent} + \beta_2 * \%\Delta\ \text{Brent}(-1) + \ldots + \beta_x \%\Delta\ \text{Brent}(t-i)$$

The expanded model is constructed with control variables that have added value for the model, meaning that these variables have a presumed relationship with inflation and inflation expectations and also increase the explanatory power of the model. It should increase the adjusted R-squared and show a better fit in the residual graph. The expanded model is formally noted as follows:

$$\text{Inflation rate} = \beta_0 * \text{Constant} + \beta_1 * \%\Delta\ \text{Brent} + \beta_2 * \%\Delta\ \text{Brent}(-1) + \ldots + \beta_x \%\Delta\ \text{Brent}(t-i) + \gamma_1 * \%\Delta\ \text{Control Variable} + \gamma_2 * \%\Delta\ \text{Control Variable}(-1) + \ldots + \gamma_x * \%\Delta\ \text{Control Variable}(t-i)$$

The last stage of modelling consists of adding dummy variables for the disturbances present in the data. Dummy variables are included if they are significant for that respective time period where a disturbance is present. Dummy variables should also improve the explanatory power of the model in terms of a better adjusted R-squared and a better visible fit in the residual graph. The final model is noted as follows:

Inflation rate = β_0*Constant + β_1*%Δ Brent + β_2*%Δ Brent(-1) + … + β*%Δ Brent(t-i) + λ_1*(Dummy*%Δ Brent) + λ_2*(Dummy*%Δ Brent(-1)) + … + λ*(Dummy*%Δ Brent(t-i)) + γ_1*%Δ Control Variable + γ_2*%Δ Control Variable(-1) + … + γ*%Δ Control Variable(t-i)

β = coefficient of independent variable

γ = coefficient of control variable

*λ = coefficient of dummy*independent variable*

t = current month

i = number of months dating back

Dummy = { 0, 1 }

Based on these model the following hypothesises will be tested:

H_0: Oil prices do not have significant impact on inflation expectations (β=0)

H_a: Oil prices have significant impact on inflation expectations (β>0) (positive relationship)

H_0: Oil prices do not have significant impact on inflation in terms of CPI (β=0)

H_a: Oil prices have significant impact on inflation in terms of CPI (β>0) (positive relationship)

H_0: Oil prices do not have significant impact on inflation in terms of core CPI (β=0)

H_a: Oil prices have significant impact on inflation in terms of core CPI (β>0) (positive relationship)

To assess whether β is greater than 0 the Wald coefficient test will be used. The Wald tests if the estimate β deviates significantly from a certain value determined in the null hypothesis (mostly 0). If β deviates significantly from that certain value we can assume that β is not equal to, greater than or less than that certain value. The Wald test can also be used to test if multiple β's are jointly significant which will be useful for any additional lags and/or dummy variables.

Results

In this section the results of the analysis are presented. At first the inflation expectations are being analysed and thereafter the effects of oil prices on inflation in terms of CPI and core CPI. Auto correlation was present in all baseline models of the dependent variables and thus a lagged dependent variable is implemented to eliminate auto correlation (see appendix A). In order to assess whether the baseline is an improvement over the AR model I will compare the (adjusted) R-squared (see appendix B). Correlograms and Breusch-Godfrey tests were analysed to assess whether auto correlation was still present after implementing the LDV's (appendix C).

I *Inflation expectations and oil prices*

Dependent variable:	5Y5Y Inflation swap rate			*Table 1*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.0844673	0.072966	1.160453	0.2481
Annual %Δ Brent	0.021118	0.026368	0.800894	0.4247
5Y5Y Inflation swap rate(-1)	0.960270	0.032313	29.71799	0.0000

F-statistic	225.3417	R-squared	0.900273
Prob. F-statistic	0.000000	Adjusted R-squared	0.898638

The addition of the annual percentage change in oil prices show marginal improvements in R-squared and the adjusted R-squared. In its most basic form there is no significant relationship visible as the estimated coefficient of the percentage change in Brent is not significant. Therefore it cannot be interpreted at the moment.

Extending the model with additional control variables results in the following estimates:

Dependent variable:	5Y5Y Inflation swap rate			*Table 2*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.124103	0.076060	1.631645	0.1054
Annual %Δ Brent	0.012522	0.026358	0.475077	0.6356
ECB MM interest	0.010630	0.004560	2.331207	0.0214
Annual %Δ Real Eff. Exchange	0.092315	0.162473	0.568184	0.5710
Annual %Δ Refinance ops.	0.019804	0.014838	1.334631	0.1845
5Y5Y Inflation swap rate(-1)	0.934887	0.034564	27.04822	0.0000

F-statistic	225.3417	R-squared	0.904472
Prob. F-statistic	0.000000	Adjusted R-squared	0.900458

The expanded model shown above still shows no significance in the coefficient of the Brent oil price, therefore it cannot be interpreted. The coefficient dropped slightly implying that the coefficient of the baseline model was positively biased. The ECB money market interest rate coefficient implies that a 1% point increase in the interest rate leads to a 0.011% point increase in the inflation swap rate. This is economically counterintuitive because a higher interest rate for household loans makes borrowing more expensive. People will be less inclined to borrow at a high rate and thus consumption declines alongside inflation expectations. In terms of goodness of fit the model, both R^2 and the adjusted R^2 have just slightly improved in comparison with the baseline model.

The third stage of modelling will include the dummy variable for the 2008-2009 financial crisis which seems to be a large disturbance looking at the graphs of the data section(figures 1,2 and 3).

Dependent variable:	5Y5Y Inflation swap rate			*Table 3*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.403030	0.108735	3.706542	0.0003
Annual %Δ Brent	0.080193	0.035271	2.273633	0.0248
D*(Annual %Δ Brent)	- 0.028974	0.006389	- 4.534714	0.0000
ECB MM interest	0.016901	0.004244	3.982531	0.0001
Annual %Δ Real Eff. Exchange	0.079818	0.022654	0.423331	0.6581
Annual %Δ Refinance ops.	0.030875	0.161610	2.760161	0.0067
5Y5Y Inflation swap rate(-1)	0.862333	0.039221	21.98649	0.0000

F-statistic	205.0491	R-squared	0.912482
Prob. F-statistic	0.000000	Adjusted R-squared	0.908032

The coefficient of the Brent has become significant with the inclusion of dummy variable (table 3). The dummy variable is implemented for the time period of Q3 2008 until Q1 2009, the oil prices abruptly went up and down in this time period. The 5Y5Y swap rate remained relatively stable during the financial crisis, possibly caused by the long term characteristic of the variable. Thus it seems logical that the impact of oil prices is somewhat lessened in that time period. In the time frame of Q3 2008 until Q1 2009 this estimate is decreased by 0.029%. In times outside of that particular time period, oil price increases of 1% lead to an increase of 0.08% in inflation expectations compared to 12 months earlier. The money market interest rate still has a significant positive impact on inflation expectations. Additionally, the percentage change in refinance operations volumes has a positive impact on inflation expectations which is economically intuitive. If refinance volumes increase by 1% compared to last year then inflation expectations rise with 0.031%.

The final model (table 3) again shows small improvements in both R^2 and the adjusted R^2. In terms of goodness of fit the model has improved on obtaining more reliable and significant estimates. However, the model contains a LDV that explains a major share of the variance in the dependent which is expected. The added variables do not add much explanatory power in terms of R-squared and the adjusted R-squared.

Looking at the residual graph of the final model (figure 4) it is visible that the fitted model is following the actual data as expected. The LDV is clearly visible as the fitted line seems to lag one month behind. The residuals show heteroskedastic standard errors and thus the use of the HAC estimator is justified.

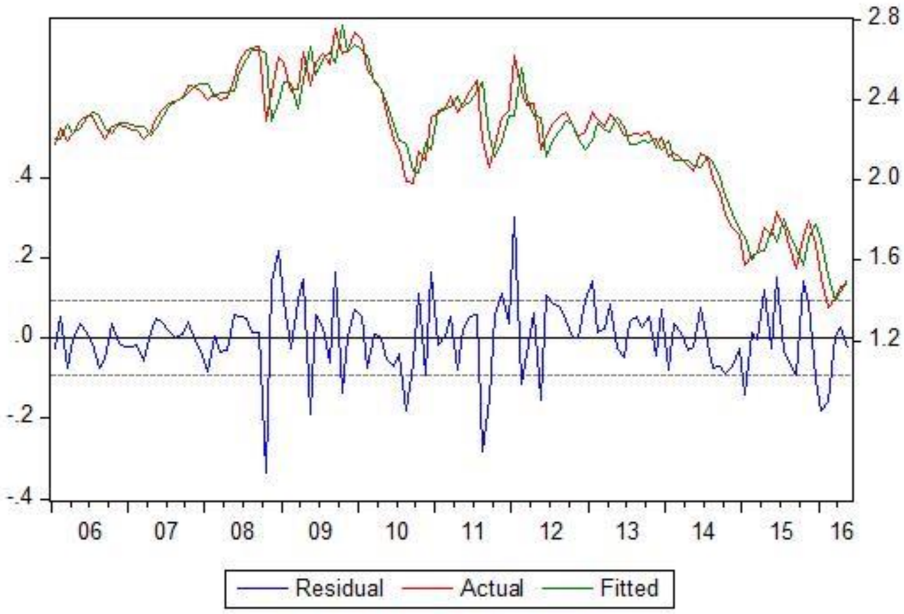

Figure 4: Actual, Fitted Residual Graph 5Y5Y Inflation swap rate

Serial correlation does not seem to be present in the final model (table 3) as seen in the correlogram (appendix C). There are no significant Q-statistics visible in these twelve residual lags, hence a Breusch-Godfrey test will not be needed to assess whether serial correlation is present or not. We can conclude that there is no serial correlation present with the inclusion of the LDV and thus the coefficients can be interpreted.

To statistically state that there is a positive relationship we test the whether β greater is than 0.

Wald test coefficients final model

Null Hypothesis: $\beta_2=0$, $\beta_3=0$

Test Statistic	**Value**	**df**	**Prob.**
F-statistic	13.34894	(2,118)	0.0000

We can statistically state that β>0 and thus a positive relationship between oil prices and inflation expectations in terms of the 5Y5Y Inflation swap rate exists.

II Inflation and oil prices

Dependent variable:	CPI			*Table 4*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.225608	0.068421	3.297374	0.0013
Annual %Δ Brent	0.462136	0.081561	5.666147	0.0000
CPI(-1)	0.869684	0.031981	27.19401	0.0000

F-statistic	1560.687	R-squared	0.962385
Prob. F-statistic	0.000000	Adjusted R-squared	0.961768

In comparison with the AR model (appendix B) the baseline model (table 4) shows decent improvements in the explanatory power of the model. R-squared and the adjusted R-squared gained about 2% with the added independent variable. The baseline model of CPI shows a significant positive relationship between oil price fluctuations and inflation in terms of CPI. The annual percentage change in oil prices of the current month show a 1% increase of the oil price in the current month leads to a 0.462% increase in inflation in the current month. Keep in mind that oil price fluctuations have a considerable share in the CPI basket. It is about 20% of the total CPI (ECB, 2016).

Expanding the baseline model for CPI with control variables lead to the following results:

Dependent variable:	CPI			*Table 5*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.208926	0.061534	3.395296	0.0009
Annual %Δ Brent	0.558989	0.077589	7.204506	0.0000
ECB MM interest	0.070884	0.014473	4.897757	0.0000
Annual %Δ Real Eff. Exchange	- 1.324688	0.389933	- 3.397216	0.0009
Annual %Δ Refinance ops.	- 0.031340	0.032887	- 3.397216	0.3426
CPI(-1)	0.786147	0.033056	23.78217	0.0000

F-statistic	712.9713	R-squared	0.967697
Prob. F-statistic	0.000000	Adjusted R-squared	0.966340

The implemented control variables (table 5) improve the explanatory power by a small margin as seen in the R-squared and the adjusted R-squared. The coefficient of the annual percentage change in Brent increased and thus implying a negative bias in the baseline model. Increases of 1% in oil price for the current month leads to an increases of 0.559% in inflation. The money market interest rate has a significant positive relationship with CPI where inflation in terms of CPI increases with 0.071% when the interest rate rises with 1%. This is, as mentioned before, economically counterintuitive. The real effective exchange rate seems to have a considerable impact on CPI where a 1% increase in the exchange rate, compared to last year, leads to a 1.325% decrease in inflation in terms of CPI.
CPI is relatively sensitive to oil price fluctuations compared to the 5Y5Y inflation swap rate and the core CPI. It follows the developments of oil prices quite closely as seen in figures 1 and 2, even during the 2008-2009 financial crisis. Consequently, there is no valid reason to include a dummy variable for inflation in terms of CPI. The second stage model with the control variables will be taken as the final model here.

The final model (table 5) with the added independent variable and control variables shows a marginal improvement in explanatory power. The annual percentage change in oil prices seems to have a larger impact on CPI than the inflation swap rate. Which was to be expected considering that oil price fluctuations are incorporated in the CPI basket. Moreover, the CPI is a short term variable compared to the long term characteristics of the swap rate as explained in the data section.

The residual graph of the final model (figure 5) shows a similar picture to that of the inflation swap rate, where the fitted line seems to lag one month behind due to the LDV. The LDV explains most of the variance in the dependent variable as to be expected. The residuals again show the presence of heteroskedasticty, thus HAC was needed to get more reliable estimates. Concluding, it is really important to know that oil price fluctuations are incorporated in the CPI basket. Therefore it is insightful to look at core CPI as well which excludes oil price fluctuations.

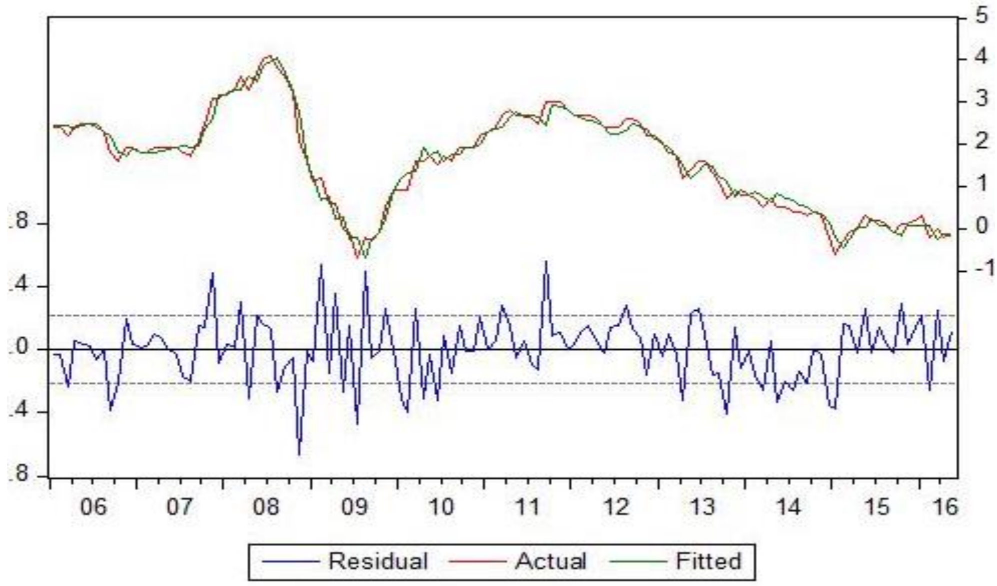

Figure 5: Actual, Fitted Residual Graph CPI

The correlogram of the final model of CPI (appendix C) shows signs of significant auto correlation in the second and twelfth lag. The remaining lags come close to significant levels of auto correlation. To test whether serial correlation is present we use the Breusch-Godfrey test for serial correlation up to the sixth lag.

Breusch-Godfrey serial correlation test final model (table 5)

Test Statistic	**Value**	**df**	**Prob.**
F-statistic	1.578364	(6,112)	0.1599

This result shows that no significant auto correlation is present up to the sixth lag of the residuals. Consequently, the coefficients can be interpreted. The twelfth lag may pose a problem as it seems to be a quite significantly serially correlated residual. This may indicate seasonality as it is the twelfth lag meaning the residual of a year back. Interpreting the coefficients of the final model of CPI should be done with care due to the residuals being close to significant auto correlation and the significant twelfth lag.

To statistically state if there is a positive relationship we test the whether β greater is than 0.

Wald test coefficient final model (table 5)

Null Hypothesis: $\beta_2=0$

Test Statistic	**Value**	**df**	**Prob.**
F-statistic	51.90491	(1,119)	0.0000

We can statistically state that β>0 and thus a positive relationship between oil prices and inflation in terms of CPI exists.

Core CPI

Dependent variable:	Core CPI			*Table 6*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.125853	0.043027	2.924953	0.0041
Annual %Δ Brent(-2)	0.023960	0.095240	0.251577	0.8018
Annual %Δ Brent(-3)	0.038455	0.092606	0.415253	0.6787
Core CPI(-1)	0.903404	0.032033	28.20224	0.0000

F-statistic	207.2958	R-squared	0.840516
Prob. F-statistic	0.000000	Adjusted R-squared	0.836462

The baseline model (table 6) of core CPI is quite different since oil price fluctuations are not included in the core CPI basket. The effects of said fluctuations on price levels might come later. The second round effect of oil price fluctuations are taken in account here with the implemented second and third lag, meaning the annual percentage change in oil prices two and three months back. The coefficients of the two lags show no significance and thus there is no significant positive relationship visible at this point. Some improvements have been made in R-squared and the adjusted R-squared in comparison with the AR model (appendix B).

Expanding the baseline model with control variables leads to the following results:

Dependent variable:	Core CPI			*Table 7*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.230224	0.057759	3.985922	0.0001
Annual %Δ Brent(-2)	- 0.014815	0.101588	- 0.145830	0.8843
Annual %Δ Brent(-3)	0.027020	0.096284	0.280627	0.7795
ECB MM interest	0.059722	0.014402	4.146793	0.0001
Annual %Δ Real Eff. Exchange	- 0.253853	0.232314	- 1.092718	0.2768
Annual %Δ Refinance ops.	- 0.001043	0.020373	- 1.092718	0.9593
Core CPI(-1)	0.730865	0.062221	11.744626	0.0000

F-statistic	118.1552	R-squared	0.860425
Prob. F-statistic	0.000000	Adjusted R-squared	0.853143

The expanded model (table 7) shows no visible positive relationship between second round effects of oil price fluctuations and inflation in terms of core CPI, despite the added control variables. In terms of the (adjusted) R-squared, improvements have been made once again due to the added variables. The money market interest rate shows a positive relationship with core CPI where a 1% increase in the interest rate leads to a 0.06% in inflation in terms of core CPI.

Looking at the graphs of figure 1 and 2 we can see that the 2008-2009 financial crisis creates a disturbance in the presumed relationship between oil prices and core CPI, similar to the situation with the swap rate. Therefore dummy variables will be implemented for that particular timeframe. The results of implementing these variables are presented below:

Dependent variable:	Core CPI			*Table 8*
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.188128	0.071809	2.619825	0.0100
Annual %Δ Brent(-2)	- 0.024740	0.113175	- 0.218600	0.8274
D*(Annual %Δ Brent(-2))	- 0.019461	0.013222	- 1.471875	0.1438
Annual %Δ Brent(-3)	0.024714	0.105470	0.259919	0.7954
D*(Annual %Δ Brent(-3))	0.025918	0.012866	2.014438	0.0463
ECB MM interest	0.059040	0.013737	4.297845	0.0000
Annual %Δ Real Eff. Exchange	- 0.277770	0.229512	- 1.210262	0.2287
Annual %Δ Refinance ops.	0.000711	0.020607	0.034498	0.9725
Core CPI(-1)	0.742194	0.0621172	12.13288	0.0000

F-statistic	88.13547	R-squared	0.861872
Prob. F-statistic	0.000000	Adjusted R-squared	0.852093

The addition of the dummy variables (table 8) does not have much added value for the model, there is still no evidence for a positive relationship between oil prices and inflation in terms of core CPI. The coefficients are far from significance sitting at a 0.80 significance level. Moreover, the adjusted R-squared worsened with the addition of the dummy variables despite their relatively significant coefficients. The residual graph of the final model shows a good fit due to the LDV included in the model to eliminate the presence of auto correlation. It also visible that the residuals of the final model (table 8) are highly heteroskedastic throughout the whole time frame, more heteroskedastic than the other inflation indices. There is a lot of erratic movement if looked upon closely.

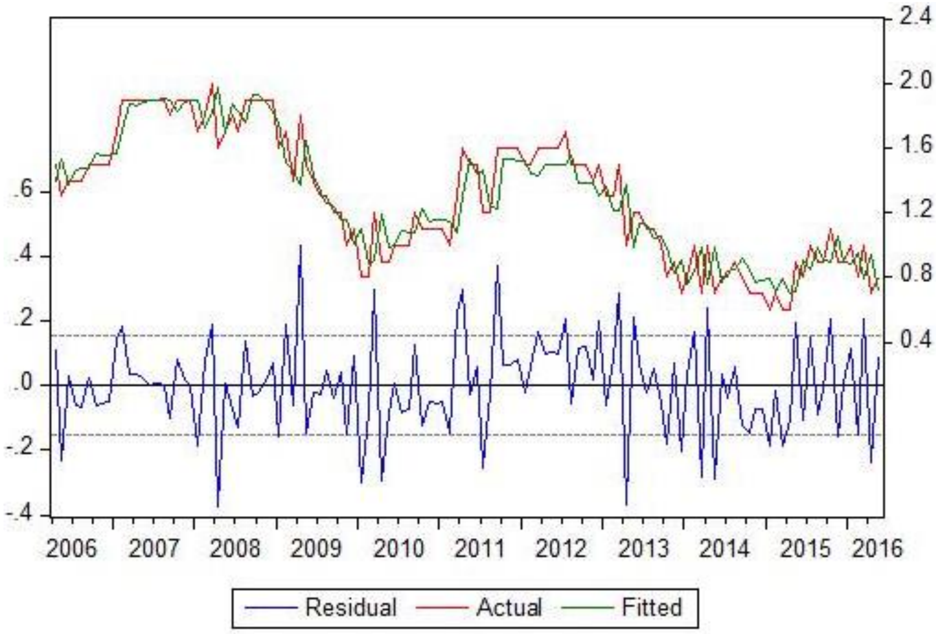

Figure 6: Actual, Fitted Residual Graph Core CPI

The correlogram of the final model of core CPI (appendix C) shows signals of serial correlation in the fourth, fifth and sixth lag of the residuals respectively. In order to determine whether these lagged residuals are significantly autocorrelated we use the Breusch-Godfrey test for serial correlation once again. We test whether the residuals up to the sixth lag are serially correlated or not.

Breusch-Godfrey serial correlation test final model (table 8)

Test Statistic	**Value**	**df**	**Prob.**
F-statistic	2.022702	(6,108)	0.0687

The results shows an insignificant probability that the residuals up to the sixth lag are serially correlated. Therefore we can interpret the coefficients of the final model of core CPI. It should be done with care as the results are quite close to being significant as was the case with CPI.

Adding any control variables or dummy variables did not change the fact that the relationship between oil prices and inflation in terms of core CPI is non-existent. Even though the overall trend of core CPI in figure 1 showed promise. Hereby we can also conclude that the null hypothesis, stating that β is equal to 0, cannot be rejected. Thus no evidence of a positive relationship could be found in this particular setting and time frame.

Conclusion & Discussion

In conclusion, evidence for the presumed positive relationships between inflation, inflation expectations and oil prices were found in the CPI and the inflation swap rate variables. Although the impact of oil price fluctuations seem marginal in the case of inflation expectations. Short term oil price fluctuations do have significant influence on the swap rate but it is relatively small due to the long term characteristic of the 5Y5Y inflation swap rate. Oil price fluctuations have a considerable influence on inflation in terms of CPI. However, it is likely that this is mostly explained by the fact that these oil price fluctuations are incorporated in the CPI basket. Still it shows that oil prices have a direct and considerable effect on the overall CPI levels. Taking the oil price fluctuations out of the equation we get the core CPI which was also tested in this thesis. There was no significant relationship visible between oil prices and inflation in terms of core CPI. Oil price fluctuations do not seem to have an effect on the prices of goods included in the core CPI basket, even if we account for the second round effects. In comparison with the previous literature we can see similarities with the results that they obtained. Previous literature mentioned that a relationship between oil prices and inflation, inflation expectations is present. The strength of this relationship has been eroding ever since the 1980's and this trend seems to be present in this thesis' setting and timeframe in terms of the swap rate and core CPI (Leblanc & Chinn, 2004) (Hooker,2002). O'Neill, Penm and Terrell (2008) mentioned that a long term relationship was not clearly visible, despite a clear short term relationship. This is partially in line with the results in CPI, core CPI and the inflation swap rate. To conclude this section we answer the research question: *Do low world oil prices undermine ECB's monetary policy, to stabilize inflation, by creating a downward pressure on inflation and inflation expectations?* Low world oil prices only have a marginal influence on inflation expectation levels and thus to state that they undermine ECB's policy is not correct. In the short run oil price fluctuations have a considerable impact in terms of CPI but this is mostly due to the fact that oil prices are incorporated in the CPI basket. Additionally, short run fluctuations in oil prices do not have a significant impact on core CPI even considering the second round effects. Thus it is debatable whether low oil prices create a downward pressure on inflation.

This thesis naturally does have its limitations. First of all, my knowledge on statistics is limited to some of the many statistical methods of estimating relationships between variables. Considerable amounts of literature used different statistical methods of estimating the relationship between inflation (expectations) and oil prices. Statistical methods that are beyond my current knowledge of statistics unfortunately. I suggest constructing a more enhanced model where serial correlation is nowhere near present as this results in better interpretation of the coefficients. I would, consequently, like to suggest further research on this topic with other statistical methods that might be more optimal. It is quite a rare phenomenon the low oil prices we have today. I would also suggest to involve the output gap in this analysis as this has been related to inflation ever since the Phillips curve. This variable has proven to be too difficult to implement for my knowledge of statistics.

Little evidence on a clear and strong relationship draws the conclusion that low oil prices do not considerably undermine the ECB's policy of stabilizing inflation. As for a policy recommendation I would suggest to look at other aspects that might cause the dangerously low inflation level. The effect of oil price fluctuations seems to be diminishing over the last as mentioned in the literature. However, it is helpful to continue establishing an economy that becomes less and less reliant on oil.

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Appendix

A)

Equation: EQ_BASE_CORE_CPI Workfile: OUTPUT_THESIS (1)::Da...

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: CORE_CPI
Method: Least Squares
Date: 07/28/16 Time: 14:35
Sample (adjusted): 2006M04 2016M05
Included observations: 122 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.314688	0.072971	18.01651	0.0000
LOG(CRUDE_OIL_PRICE_BRENT(-2))-L...	-0.125444	0.420293	-0.298467	0.7659
LOG(CRUDE_OIL_PRICE_BRENT(-3))-L...	0.413856	0.377029	1.097677	0.2746

R-squared	0.097194	Mean dependent var	1.295902
Adjusted R-squared	0.082021	S.D. dependent var	0.399048
S.E. of regression	0.382333	Akaike info criterion	0.939231
Sum squared resid	17.39521	Schwarz criterion	1.008183
Log likelihood	-54.29312	Hannan-Quinn criter.	0.967237
F-statistic	6.405660	Durbin-Watson stat	0.192885
Prob(F-statistic)	0.002280	Wald F-statistic	2.604446
Prob(Wald F-statistic)	0.078155		

Equation: EQ_BASE_5Y5Y Workfile: OUTPUT_THESIS (1)::Data_te...

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: INFLATION_SWAP_RATE_5Y5Y
Method: Least Squares
Date: 07/28/16 Time: 14:36
Sample (adjusted): 2006M01 2016M05
Included observations: 125 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.246865	0.042082	53.39202	0.0000
LOG(CRUDE_OIL_PRICE_BRENT)-LOG(...	0.296623	0.187436	1.582531	0.1161

R-squared	0.163065	Mean dependent var	2.223898
Adjusted R-squared	0.156261	S.D. dependent var	0.307215
S.E. of regression	0.282193	Akaike info criterion	0.323421
Sum squared resid	9.794861	Schwarz criterion	0.368674
Log likelihood	-18.21383	Hannan-Quinn criter.	0.341805
F-statistic	23.96483	Durbin-Watson stat	0.117322
Prob(F-statistic)	0.000003	Wald F-statistic	2.504404
Prob(Wald F-statistic)	0.116096		

Equation: EQ_BASE_CPI Workfile: OUTPUT_THESIS (1)::Data_test\

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: CPI
Method: Least Squares
Date: 07/28/16 Time: 14:35
Sample (adjusted): 2006M01 2016M05
Included observations: 125 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed
bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.743004	0.151468	11.50739	0.0000
LOG(CRUDE_OIL_PRICE_BRENT)-LOG(...	2.043305	0.333704	6.123116	0.0000

R-squared	0.540252	Mean dependent var	1.584800
Adjusted R-squared	0.536514	S.D. dependent var	1.162662
S.E. of regression	0.791538	Akaike info criterion	2.386193
Sum squared resid	77.06346	Schwarz criterion	2.431446
Log likelihood	-147.1370	Hannan-Quinn criter.	2.404576
F-statistic	144.5379	Durbin-Watson stat	0.147908
Prob(F-statistic)	0.000000	Wald F-statistic	37.49254
Prob(Wald F-statistic)	0.000000		

B) AR(1) models for comparison with baseline model

Dependent variable: 5Y5Y Inflation swap rate

Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.061299	0.064082	0.956567	0.3405
5Y5Y Inflation swap rate(-1)	0.969815	0.028212	34.37563	0.0000

F-statistic	1154.145	R-squared	0.895974
Prob. F-statistic	0.000000	Adjusted R-squared	0.895198

Dependent variable: CPI

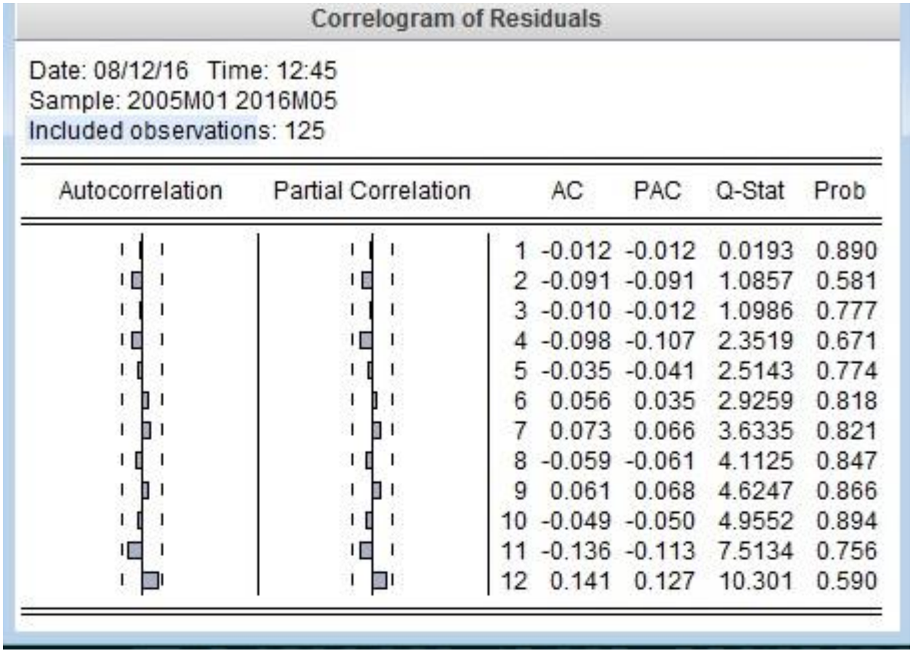
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.016258	0.046756	0.347730	0.7286
CPI(-1)	0.981234	0.026123	37.56139	0.0000

F-statistic	2355.975	R-squared	0.946180
Prob. F-statistic	0.000000	Adjusted R-squared	0.945779

Dependent variable:	Core CPI			
Variable	**Coefficient**	**St. error**	**t-stat.**	**Prob.**
C	0.107278	0.037625	2.851264	0.0050
Core CPI(-1)	0.913540	0.029023	31.47662	0.0000

F-statistic	641.9692	R-squared	0.827313
Prob. F-statistic	0.000000	Adjusted R-squared	0.826024

C) Correlograms of final models 5Y5Y swap rate, CPI, Core CPI



Correlogram of Residuals

Date: 08/12/16 Time: 12:45
Sample: 2005M01 2016M05
Included observations: 125

	AC	PAC	Q-Stat	Prob
1	-0.012	-0.012	0.0193	0.890
2	-0.091	-0.091	1.0857	0.581
3	-0.010	-0.012	1.0986	0.777
4	-0.098	-0.107	2.3519	0.671
5	-0.035	-0.041	2.5143	0.774
6	0.056	0.035	2.9259	0.818
7	0.073	0.066	3.6335	0.821
8	-0.059	-0.061	4.1125	0.847
9	0.061	0.068	4.6247	0.866
10	-0.049	-0.050	4.9552	0.894
11	-0.136	-0.113	7.5134	0.756
12	0.141	0.127	10.301	0.590

Swap Rate Final Model (Table 3) Correlogram

Correlogram of Residuals

Date: 08/12/16 Time: 14:04
Sample: 2005M01 2016M05
Included observations: 125

	AC	PAC	Q-Stat	Prob
1	0.020	0.020	0.0501	0.823
2	0.181	0.181	4.2970	0.117
3	-0.102	-0.112	5.6396	0.131
4	0.135	0.113	8.0214	0.091
5	-0.061	-0.034	8.5143	0.130
6	0.146	0.102	11.340	0.078
7	0.142	0.183	14.035	0.051
8	-0.004	-0.091	14.037	0.081
9	0.054	0.052	14.442	0.107
10	-0.063	-0.059	14.992	0.132
11	0.133	0.100	17.452	0.095
12	-0.306	-0.308	30.584	0.002

CPI Final Model (Table 5) Correlogram

Correlogram of Residuals

Date: 08/12/16 Time: 14:40
Sample: 2005M01 2016M05
Included observations: 122

	AC	PAC	Q-Stat	Prob
1	-0.074	-0.074	0.6894	0.406
2	-0.099	-0.105	1.9251	0.382
3	0.087	0.072	2.8825	0.410
4	-0.149	-0.150	5.7248	0.221
5	0.170	0.173	9.4772	0.091
6	0.171	0.163	13.305	0.038
7	-0.024	0.061	13.378	0.063
8	0.109	0.111	14.940	0.060
9	-0.122	-0.091	16.934	0.050
10	-0.017	0.003	16.974	0.075
11	0.016	-0.090	17.010	0.108
12	-0.088	-0.103	18.071	0.114

Core CPI Final Model (Table 8) Correlogram