

## **What are the Causes of High Crude Oil Price? Causality Investigation\***

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**ABSTRACT:** This paper examines the development of oil prices and identifies the main causes of their development in the last three decades. Of course there are many factors influencing the oil prices, predictable market factors (such as demand and supply) and unpredictable factors (such as political and social turmoil). Therefore, this paper will empirically try to identifying the main causes of movement of the oil prices. This paper also has an ambition to test relation between crude oil and natural gas prices, as substitutes, and the role of decline of natural gas prices in stabilization or destabilization the crude oil market. We have had used in this paper qualitative and quantitative methods such as regression model, Granger causality and structural models. The main findings we have gotten are that the US dollar exchange rate has a significant role in the development of oil prices. We think that the decline in natural gas (as a substitute) prices in the last two years has a slightly impact on stabilization of the oil prices.

**Keywords:** Crude oil prices; natural gas prices; US dollar exchange rate; granger causality; structural model

**JEL Classifications:** C32; Q41; Q43

### **1. Introduction**

Oil prices are traditionally influenced by more than one factor. In addition to the fundamental market factors (Supply and demand) there are many others, such as, speculation in the crude oil markets, the less predictable factors (political instability hurricanes, tsunamis, etc.), the US Dollar exchange rate as a more discussed factor in the energy-economic literature at least in the last two decades and other factors like capacity of the so-called downstream sector. Furthermore crude oil as a commodity is influenced by the price of its substitute(s). Since oil price is often much volatilized and affects not only prices of other commodities, which are essential for food, chemical and other industries, but subsequently affects the macroeconomic indicators of oil exporting and importing countries, is indeed a subject of many studies, expert's discussions and analyses.

The objective of this paper is to provide a further contribution to analyse the correlation between oil prices and the main fundamental factors influenced them such as supply, demand, US dollar exchange rate and prices of natural gas as the most important substitute of oil, and to draw some conclusions about the oil market. Regarding natural gas price, economic theory suggests that natural

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gas and crude oil prices should be related because the both energy commodities are substitutes in consumption and also complements, as well as rivals, in production. In addition to the qualitative analyses, as the research method we are using regression model, Granger causality, structural model and ECM to identify the causes of high oil prices among with the relation between the crude oil and natural gas prices.

## **2. Literature Review and Theoretical Discussion**

Oil prices are influenced by fundamental market factors and non-market factors. In addition to the fundamental market factors (Supply and demand as well as the US Dollar exchange rate and other factors like capacity of the so-called downstream sector), there are many others non-market factors which impacts have risen in the last decades such as, speculation in the crude oil markets, the less predictable factors (political instability hurricanes, tsunamis, etc. (Obadi and Othmanová, 2012). Since natural gas prices in the last decade have been much fluctuated and the prices of the two most tradable types of natural gas has an opposite directions it could theoretically affect the development of oil prices. Though usually the direction of impact is from oil prices. Therefore, in this paper we will investigate the possible impact of natural gas price declining (the spot prices in natural gas hubs) on the movement of oil prices.

It is important to point out that from a demand perspective oil and natural gas are competitors, which means that they are two different sources of energy and in economic theory if one becomes too expensive people will switch to the other one. Indeed, in reality it is very hard to switch in the short term as the infrastructure to turn either in to energy is very different. A natural gas fired power plant cannot just start pumping in crude oil if oil becomes cheap. Also, refining capacity for crude oil is tight. One of the biggest problems with natural gas is the difficulty of storing and transporting it. If there is no existing pipeline infrastructure, new infrastructure must be built or very new and expensive LNG (Liquefied Natural Gas) technology must be installed. For this reason in the short to medium term the price of gas relative to liquids can diverge greatly from the logical relationship based on the amount of energy derived from each source. Though many natural gas customers or households in USA after the sharp decline of natural gas prices for heating in the last decade have switched to heating by natural gas.

In causality perspective many studies theoretically and empirically examined the impact of oil prices on dollar real effective exchange rate (see Coudert et al., 2008). They find that causality runs from oil prices to the exchange rate. "... as we investigate the channels through which oil prices affect the dollar exchange rate, we find out that the link between the two variables is transmitted through the U.S. net foreign asset position". In the same link Amano and van Norden (1998) examined whether a link exists between oil price shocks and the U.S. real effective exchange rate. They used the single-equation error correction and find that the two variables appear to be co-integrated and that causality runs from oil prices to the exchange rate and not vice versa. "The results suggest that oil prices may have been the dominant source of persistent real exchange rate shocks over the post-Bretton Woods period and that energy prices may have important implications for future work on exchange rate behaviour" Amano and van Norden (1998). According to Bénassy-Quéré et al. (2005), the relationship between oil price and USD exchange rate is clear. They provided evidence of a long-term relation (i.e. a cointegration relation) between the two series in real terms and of a causality running from oil to the dollar, over the period 1974-2004. Their estimation suggests that a 10% rise in the oil price leads to a 4.3% appreciation of the dollar in real effective terms in the long run. The estimation of an error correction model shows a slow adjustment speed of the dollar real effective exchange rate to its long-term target (with a half-life of deviations of about 6.5 years). Although consistent with previous studies, our results are unable to explain the period 2002-2004 with a rising oil price and a depreciating dollar.

On the other hand, many other studies examined the impact of US dollar exchange rate on oil price; see e.g. Alhajji (2004); Cheng (2008); Krichene, (2005); Yousefi and Wirjanto (2004). According to Alhajji, "US Dollar depreciation reduces activities in upstream through different channels including lower return on investment, increasing cost, inflation, and purchasing power. Furthermore, US Dollar devaluation increases demand in countries with appreciated currencies

because of increase in purchasing power and increases demand in the US as tourists prefer to spend their vacations in the US". In case of US Dollar depreciation, the revenues of oil exporting countries, at least those whose local currencies are tied to US Dollar, are more or less decreased. This leads to a deterioration of their terms of trade, because they must export more units of crude oil to get the same amounts of imported products for example from Europe, than they had to before US Dollar depreciation. Therefore, oil exporting countries are inclined to maintain oil prices high as much as appropriately in proportion to the US Dollar depreciation, and alleviate the loses in their oil revenues. In the same link, Krichene (2005) examined the relation between oil prices, interest rates and US Dollar exchange rate NEER. In his study the attention was given to shocks arising from monetary policy—namely, shocks to interest and exchange rates. He used a vector autoregressive model (VAR) to analyze cointegration between crude oil prices, the dollar's NEER, and U.S. interest rates based on monthly, quarterly, and annual data. He reported that VAR analyses did not reject the existence of at least one cointegration relation. Although the cointegrating coefficients change both in sign and statistical significance according to frequency, sample period, and the number of lags, there is nevertheless a stylized relation during periods of large movements in interest and exchange rates. While an interest rate shock generally affects negatively and significantly oil prices for most of the sample periods, the effect of a NEER shock is significantly negative, essentially during periods of large movements in interest and exchange rates (Krichene, 2005).

In the economic perspective, other empirical studies in this link found a negative linear relationship between oil prices and economic activity in oil importing countries. However, in the mid 80s it was indicated that the linear relationship between oil prices and economic activity began to lose statistical significance. Mork (1989), Lee et al. (1995) and Hamilton (1996) introduced the nonlinear transformation of oil prices to explain the negative relationship between the rise in oil prices and economic downturn and to prove Granger causality between these two variables. Jiménez-Rodríguez (2004) also confirmed, on the example of USA, the existence of non-linear relationship between these variables. The importance of oil in the world economy explains why so much effort has been put into developing different types of econometric models to predict future price developments.

### **3. Empirical Evidence**

#### ***Methodology***

In this section we describe the basic types of models. Financial models concentrate on the relationship between spot and futures prices. On the other hand, structural models explain the oil prices development by exogenous variables, which describe the physical oil market.

#### ***Structural models***

Structural models concentrate on describing the development of oil prices market through explanatory variables that describe this market. Variables that are usually used to predict oil prices can be divided into two basic groups: variables that describe the role of OPEC in world oil market and the variables that capture current and future availability of oil. Apart from the influence of OPEC, several authors emphasize the current and future physical availability of oil. With this in mind, many key variables are based on stock levels. Stocks are linkages between demand and production and consequently a good measure of variations in prices (Ye et al., 2005). Most authors distinguish two types of stocks: government stocks and industrial stocks. In terms of their origin, government stocks are not generated by real demand and supply. This explains the decision of many economists to put into models industrial stocks, which are changing within a short time and can capture the dynamics of oil prices. In the same link, Zamani (2004) has presented short-term forecasting models for WTI crude oil prices, where he incorporated both groups of variables, the physical availability of oil and the role of OPEC.

His model looks as follows:

$$S = \beta_1 + \beta_2 OQ + \beta_3 OV + \beta_4 RIS + \beta_5 RGS + \beta_6 DN + \beta_7 D90 + \varepsilon \quad (1)$$

Where:

OQ is fixed production quota issued by OPEC, the OV is overrun of this quota, and RIS is relative industrial stocks given by equation:  $RIS = IS - ISN$ , where IS is value of industrial stocks and ISN is normal level of industrial stocks. RGS is relative government stocks given by equation:  $RGS = GS - GSN$ . Variable DN is a demand in countries outside the OECD and D90 is a dummy variable expressing the war in Iraq during the third and fourth quarter of 1990. Zamani used quarterly data for

the period from 1988 to 2004. He suggested that an increase in all explanatory variables leads to a reduction of the oil prices, while the dummy variable and demand in non-OECD positively affect the price.

How OPEC decisions influence the oil price development?

The role of OPEC in the world oil markets has been examined by the academic community several years. Many studies brought evidence that OPEC has an ability to influence real oil prices, although in the recent years the demonstrated impact of the organization decreases. Many econometric analyses show that there was a statistically significant relationship between real oil prices and the following variables: capacity utilization by OPEC, OPEC quotas, exceeding the amount of these quotas (overproduction) and oil reserves in countries OECD (Organization for Economic Co-operation and Development). Between the abovementioned variables the existence of a Granger causality is demonstrated. These variables causally affected the real oil prices, but oil prices did not affect these variables. Cointegration relationship between the real oil prices, OPEC capacity utilization, quotas, and maintaining these quotas shows that OPEC plays an important role in determining the world oil prices.

### ***The impact of exchange rate of US dollar on oil prices***

In this empirical part we will focus on the impact of US dollar exchange rate against main currencies on the oil prices. From the world currencies we selected Japanese yen, Euro, and Swiss franc, using the daily frequency data for the period 1986:1:1 - 2011:8:11. In case of the European Union currency, we used German mark value (DEM) multiple by the conversion rate which was approved on value 0.5113 DEM/EUR. This conversion rate is valid from January 1<sup>st</sup> 1999. Thereby, we obtained a consistent time series for the entire period.

According to the results of correlation matrix we can say, that exchange rates have negative impact on oil price development. So when the exchange rate is increasing, the oil prices will decrease. The real impact on crude oil price we examine through regression analyses of each explanatory variable on the dependent variable.

Before we started an analysis, we have tested each variable for the presence of unit root. The incidence of unit root indicates that time series are nonstationary, and because of these results, the regression could be spurious. Integration of time series has been tested using the Augmented Dickey-Fuller test (ADF test). The null hypothesis of this test is that the series has a unit root. The null hypothesis of nonstationarity is rejected if the t-statistic is less than the critical value. Critical ADF statistic values are considerably larger (in absolute value) than critical values used in standard regression. (Critical values used in ADF test: Equation with no intercept and no trend: -2.58 (1%), -1.94 (5%), -1.62 (10%). Equation with intercept: -3.46 (1%), -2.88 (5%), -2.58 (10%). Equation with intercept and trend: -4.01 (1%), -3.43 (5%), -3.14 (10%). Lag structure of the ADF test were determined using the Akaike Information criteria. The ADF test confirmed a presence of a unit root in each variable.

The ADF test has proved that all variables are nonstationary, because they contain stochastic trend, which can be clearly seen from the time series development. Therefore, to describe long term relations between variables, we have been used cointegration analyses. Engle and Granger (1987) pointed out that a linear combination of two or more nonstationary series may be stationary. If such a stationary linear combination exists, the nonstationary time series should be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables. The output of Johansen test also provides estimates of the cointegrating relations  $\beta$  and the adjustment parameters  $\alpha_{ec}$ . We applied Johansen test between WTI and each exogenous variable. The null hypothesis of the test denotes that there is no cointegration relationship between variables.

Trace test results indicated that there is no cointegration among variables at the 0.05 significance level. So between WTI price and exchange rate USD/EUR there is no long-run equilibrium relationship. It means that in the long term point of view there is no proved relation among these variables. It may be because in Europe more often Brent crude oil, and other types of crude oil from Russia and OPEC are traded.

*Error Correction Model (ECM)*

After the confirmation of a cointegration relation between variables we established an Error Correction Model (ECM). The ECM has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics.

The basic specification of EC model looks as follows:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_{t-1} + \alpha_{ec}(y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + \varepsilon_t \quad (2)$$

where coefficient  $\alpha$  represents short dynamic and  $\beta$  long term relationship between variables  $y$  and  $x$ . Coefficient  $\alpha_{ec}$  is an error correction element, which describes the speed of correction of the deviation from long-term relationships.

From these results we clearly see the difference between the impact of Exchange rate from short and long term view. In the short term view the Exchange rate of the US dollar and the Japanese yen has a negative impact on WTI oil price. However in the long term view this impact is inverse It could be because in the long term, prices have tended to adapt to the situation of decreasing or increasing of the exchange rates. The error correction element value is 0.0008 which means that every time period deviation from long term equilibrium decreases by -0.08%. In our case this period is one day, which means that this correction is appropriate.

The estimated model is as follow:

$$\Delta WTI_t = -0.0185 - 0.1343 \Delta USDJPY_{t-1} - 0.0008(WTI_{t-1} - 0.026586 - 0.059388 USDJPY_{t-1}) + \varepsilon_{t, \dots} \quad (3)$$

Trace and maximum eigenvalue test indicated 1 cointegrating equations at the 0.05 level. So between variables there is a long term relation. Also in this relation we see differences between short and long term dynamics. In the short term period the increasing of Exchange rate causes a decrease of oil price and vice versa in the long term period. In the long term view, the impact of change of value USD/CHF is higher than USD/JPY. But in the short term the oil price is more responding to change in USD/JPY value. The error correction element is higher in relation between WTI and USD/CHF, and its value is -0.06, which means that each day the deviation from long term equilibrium decreases by 6%.

$$\Delta WTI_t = -0.0275 - 0.00971 \Delta USDJPY_{t-1} - 0.06069(WTI_{t-1} - 0.044751 - 6.250402 USDJPY_{t-1}) + \varepsilon_t \quad (4)$$

### **Structural model of oil price development**

In this section, we have created an econometric model based on monthly data that would describe the oil price development. For this purpose we have used monthly data for the period from period January 1994 to September 2010, with 201 observations.

The model is as follow:

$$WTI = \beta_0 + \beta_1 OECD + \beta_2 US + \beta_3 CHINA + \beta_4 OECDSTOCK + \beta_5 USSTOCKS + \beta_6 USCOM + \beta_7 WP + \beta_8 QUOTAS + \beta_9 CHEAT + \beta_{10} GDPGROWTH + \beta_{11} OECDAYS + \beta_{12} USEXCHANGE + \beta_{13} DUMMY + \varepsilon_t \quad (5)$$

Where:

Oil price of **WTI** (West Texas Intermediate) as dependant variable. The value of the variable WTI represents the average spot price of WTI crude oil with Incoterm FOB (Free on Board), expressed in U.S. dollars for barrel.

#### *The exogenous variables*

Demand side:

One of the important fundamental variables, which explains the situation in the oil markets is demand for this commodity, hence its consumption. With increasing consumption, demand is growing, and causing that the demand curve shifts to the right and consequently increases the price of oil. Thus, we assume that the increase of consumption and in the presence of inelastic supply curve, oil price will increase. We chose consumption of OECD countries (**OECD**) and United States (**US**), as the largest consumer of this commodity. Both variables are reported in thousands of barrels per day. We can see relatively stable growth of these variables. However, we can notice that in the dynamically growing countries such as India, Brazil and China, this growth is much higher.

Therefore, we incorporate into the model the Chinese demand for oil (**CHINA**). These data were quarterly, so we adjusted them using linear interpolation. It must be noted that these data are based on an estimation of the sum of domestic oil production and import of this commodity, because of the lack of official data on consumption.

Stocks:

After the first oil crises in the 70s and 80s of 20th century, OECD decided to set minimum stocks of oil in order to avoid unforeseen supply disruptions of this energy commodity. As explanatory

variables we chose the stocks of countries belonging to the OECD (**OECDSTOCK**) and USA (**USSTOCKS**) - the stocks of crude oil including strategic reserves and refined products. U.S. oil stocks account for about 25 percent of OECD stocks, and because of their significant share of total OECD stocks, they are reported separately. Both variables are expressed in thousand barrels. We assume that if the stocks level rises, it will cause a decrease in demand for oil and then decrease its price. The commercial oil stocks in USA (**USCOM**) were included as another variable to the model. This is the amount of reserves after deduction of Strategic Petroleum Reserves, which the U.S. federal government usually holds in case of long interruption of oil supplies. By this regressor we expect a negative impact on oil price. Furthermore, we have included a variable that has been established by Kaufmann in his study - we called it **OECDAYS** and it is calculated as a proportion of OECD stocks and OECD demand. This variable can be interpreted as a degree of independence from the OECD and OPEC price shocks.

Supply side:

In this category we include a variable that indicates the global production of oil (**WP**). It is measured in thousands of barrels per day. We assume that with increasing production, the oil price declines. OPEC, the world's largest producer as a cartel, declares raises or cuts of their production quotas (**QUOTAS**) and this information is a very important sign for the oil markets and has an impact on the oil prices. These quotas define for each member of OPEC the amount, which can be produced per day by the particular member. This variable is stated in thousands barrels per day for OPEC countries as a whole as well. Production quotas are changing at the Board meetings of OPEC as a response to current prices and demand for crude oil. We expect a negative relationship between oil prices and production quotas, thus raising the value of production quotas causes oil price to decrease. Using these restrictions, OPEC tries to control price development and maintain the stability in the oil markets. But it has been observed that their efforts were often violated by several members of the cartel (In May 2009, the OPEC's compliance with a series of cuts agreed in the second half of 2008 has reached about 80 %, and it was an unprecedented figure in OPEC's history). Therefore, we think that a violation (**CHEAT**) could be a further variable, because of its role in the supply side. It is a difference between OPEC production and their quotas and will be expressed in thousand barrels per day. We expect that an increase of violations of production quotas will cause the oil prices to decline because of overproduction.

Also we incorporated variables that describe economic activity (**GDP growth**) of selected countries, especially, the largest consumption countries, such as USA, Japan, Germany as the largest economy among European countries and China as one of the fastest growing economy in the world and the second biggest economy in the world. Because the data for this variable are available only in annual frequency, we applied the statistical method of interpolation to get monthly values. The last variable included in this model is US dollar exchange rate against euro (**USDEUR**). To capture the unforeseen factors such as geopolitical factors etc. we established a **dummy** variable that will indicate the political or climate events that might affect the development of oil prices. In such situation, the dummy variable has a value 1 and value 0 otherwise.

The included events are following:

- 11th September 2001 - the terrorist attack on the United States of America
- December 2002, January and February 2003 - General strike in the oil industry in Venezuela
- 20th March 2003 - Invasion of Iraq
- 14th September 2004 - Hurricane Ivan - the damage of oil drills in the Gulf of Mexico
- 29th August 2005 - Hurricane Katrina, which damaged oil drills in the Gulf of Mexico
- July to December 2008 – the Global financial crisis.

### ***The results of model***

Before creating the model, we tested stationarity of each variable, using ADF test, and to identify number of lags included, we have chosen Akaike information criteria. From the results of the test we see that almost each variable is nonstationary. We also tested stationarity of logarithm of WTI prices. The result of ADF test rejected the null hypothesis of nonstationarity. Because of that, we have applied a modeling logarithm of WTI prices with 198 observations after adjustments, and could

interpret it as a relative change of oil price. The list of variables that came out as significant for describing the development of oil prices are stated in the table 1.

**Table 1. The results of structural model**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.680507	0.336197	10.94749	0.0000
CHINA	0.000293	9.62E-06	30.46082	0.0000
GDP_US	-0.086903	0.015054	-5.772764	0.0000
GDP_US(-3)	0.034622	0.014790	2.340933	0.0203
DUSCOM(-1)	-4.04E-06	2.05E-06	-1.971315	0.0501
D(QUOTAS)	5.57E-05	2.27E-05	2.455246	0.0150
OECDAYS	-0.014453	0.003477	-4.156537	0.0000
USDEUR	-0.564405	0.127172	-4.438121	0.0000
DUMMY	0.135698	0.064702	2.097258	0.0373

From the results (Table 1), we can clearly see that all these variables are significant on 5% level. The R-squared of this model is 0.89, which means that the model described the oil prices for 89%. To test whether residuals are white noise, we use Breusch-Godfrey test. The null hypothesis of this test means that there is no correlation between residuals. Thus, we accept the null hypothesis on 5% significance level.

The final equation is as follows:

$$LOG(WTI) = 3.6805 + 0.0003*CHINA_t - 0.0869*GDP\_US_t + 0.0346*GDP\_US_{t-3} - 4.0938*10^{-06}*DUSCOM_{t-1} + 5.5681*10^{-05}*DQUOTAS_t - 0.0145*OECDAYS_t - 0.5644*USDEUR_t + 0.1357*DUMMY \quad (6)$$

The results of the model show that variables describing the supply side of oil are not so significant for oil price setting as much as the variables describing the demand side. In spite of that, the OPEC quotas (DQUOTAS) seem to be statistically significant, but there is a positive correlation with oil price, which does not comply with the link of our assumption. The interpretation of this result could be that the change of OPEC quotas has not an impact on oil price, because of the often low level of OPEC's compliance (Cheats). On the other hand, US commercial stocks, OECD stocks as well as the OECD strategic reserve as a whole seem to be significant and have a negative correlation with oil price. The increase of stocks of the key oil consumption countries leads to a decrease of the global demand and drop of the oil prices. In case of the GDP growth indicators they showed to be significant only for China and USA – the two largest countries in oil consumption. While the GDP growth of China has a positive impact on oil prices immediately, the GDP growth of USA has a positive impact on oil prices, but with a three months lag. However, the GDP growth of USA at time  $t$  has a negative impact. This does not correspond with our assumption, since USA is the world's largest oil consumer. However, this result would be in line with the results of other studies that have been done in relation to this issue. The negative impact of the US Dollar on oil price is marks clear evidence in the results of model that the increase of value of US Dollar against euro leads to the oil prices to decrease, or, the decrease of US Dollar exchange rate causes the oil prices to raise. Finally, the dummy variable indicates a positive correlation with the oil prices. The events leading to oil supply interruptions or to damages in the downstream sector have an impact on the oil prices.

### **3.1 Relationship between crude oil and natural gas prices**

This part examines the relationship between crude oil and natural gas prices. Considering the difference conditions between European and North American spot price of natural gas hubs and the subsequently relationship, we decided to separately analyze on the one hand the relationship between Brent prices and spot natural gas prices at European hubs and in the other hand the relationship between WTI prices and spot natural gas prices at Henry hub.

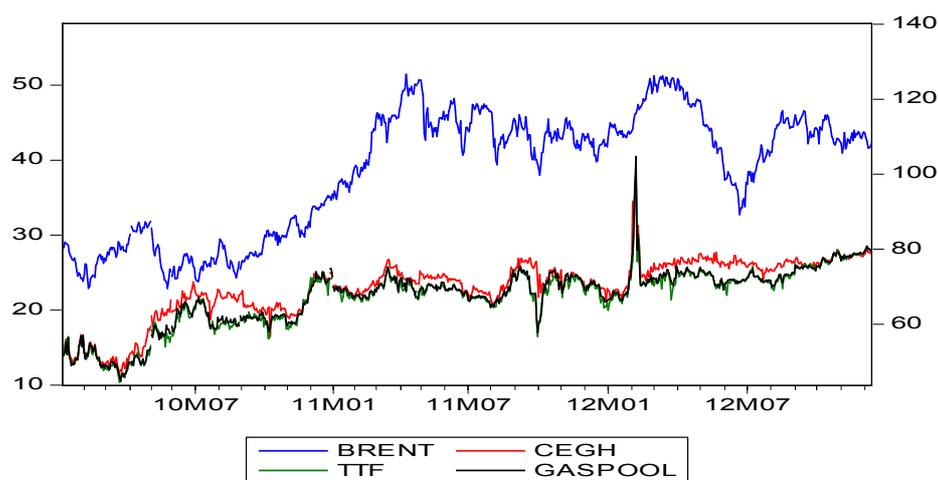
#### *Relationship between crude oil and natural gas prices on European market*

In our work we have also focused on oil and natural gas prices development in Europe. Economic theory suggests that natural gas and crude oil prices should be related because natural gas and crude oil are substitutes in consumption and also complements, as well as rivals, in production. We have selected the natural gas prices on three European hubs, the trading platforms with gas. First is Central European Gas Hub (CEGH), also known as Gas Hub Baumgarten in Austria. Second is virtual

trading point in Netherlands, Title Transfer Facility (*TTF*) and third is largest German trading point Gaspool (*GASPOOL*). We will analyze relationship between natural gas prices and Brent crude oil price (*BRENT*). We have analyzed daily frequency data for the period from January 4<sup>th</sup>, 2010 to December 11<sup>th</sup>, 2012 (figure 1). Overall, we have 757 observations for this period. All prices represent spot prices, gas prices in EUR/MWh and crude oil price in USD/barrel.

Europe is the main battleground for gas pricing. In America gas prices are set by the fundamentals of supply and demand (known as gas-on-gas competition), which means they are currently low. In Asia gas is mainly bought and sold at prices set by contracts linked directly to (currently high) oil prices. Europe is somewhere in the middle.

**Figure 1. Spot prices development of selected variables, 2010 – 2012**



Left axis - natural gas prices on CEGH, TTF and Gaspool; right axis – Brent crude oil price  
Source: Own calculation based on data from Reuters (Platts).

We have to notice, that there have been periods in which natural gas and crude oil prices have appeared to move independently of each other. Furthermore, over the past 5 years, periods when natural gas prices have appeared to decouple from crude oil prices have been occurring with increasing frequency with natural gas prices rising above its historical relationship with crude oil prices in 2001, 2003, and again in 2005. This has led us to examine whether natural gas and crude oil prices are related in recent times. For determining this relationship we will use Granger causality test. If the results will prove that there is relation between crude oil price and natural gas prices we will tested variables for a presence of unit roots, after this we used cointegration analyze to find out whether there is long term equilibrium among variables. Cointegration of economic time series suggests that the economic variables have a long-run structural relationship that can be empirically evaluated. According to cointegration analyze we can establish Error Correction Model (ECM). The ECM has built cointegration relations into the specification so that it restricts the long-run behavior

*Granger causality*

The Granger approach to the question of whether variable  $x$  causes  $y$ , is to see how much of the current  $y$  can be explained by past values of  $y$  and then to see whether adding lagged values of  $x$  can improve the explanation.  $y$  is said to be Granger-caused by  $x$  if  $x$  helps in the prediction of  $y$ , or equivalently if the coefficients on the lagged  $x$ 's are statistically significant. The null hypothesis is that  $x$  does not Granger-cause  $y$  in the first regression and that  $y$  does not Granger cause  $x$  in the second regression. The test results are given by tables 2.

The results have proved our assumption that price of Brent crude oil influence natural gas price development at selected hubs on 10% level. On the other hand we have seen that the causality from natural gas prices to crude oil is not confirmed. Using the Augmented Dickey-Fuller test (ADF test), we found that all variables are nonstationary, because they contain stochastic trend, which can be clearly seen from the time series development.

In the same time using the *Johansen cointegration test*, and according the results of Trace statistic eventually maximum Eigenvalue statistics we find that between variables (between Brent and each of CEGH, TTF and Gaspool) is a long term relationship at 0,05 % level.

**Table 2. Granger Causality test (Null hypothesis: x does not granger cause y)**

Null Hypothesis:	F-Statistic	Prob.
CEGH does not Granger Cause BRENT	0.55879	0.5721
BRENT does not Granger Cause CEGH	3.24220	0.0396
TTF does not Granger Cause BRENT	1.43618	0.2385
BRENT does not Granger Cause TTF	3.00606	0.0501
GASPOOL does not Granger Cause BRENT	1.76967	0.1711
BRENT does not Granger Cause GASPOOL	2.72178	0.0664

Source: Own calculation in Eviews 6.

After the confirmation of a cointegration relation between variables we can establish an Error Correction Model (ECM). We used Engle Granger two-step method, because we assume, that short term relation could be not significant because of using daily data.

The first step is the estimation of long run relations,  $\beta$ , in a cointegrating regression of  $y$  on  $x$ .

$$y_t = \beta_0 + \beta_1 x_t + \mu_t \quad (7)$$

In the second step, changes in  $y$  are regressed on changes in  $x$  and the previous period's equilibrium error (the residuals from the cointegrating regression) to estimate equilibrium rate  $\alpha_{ec}$  and short run dynamics  $\alpha$ .

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_t + \alpha_{ec} \mu_t + \eta_t \quad (8)$$

According the results, for all error correction model specifications, there are significant coefficients in long run part, but not in the short run. It may be because we have used the daily frequency data, so the short run dynamics is captured in development of prices. From these results we clearly see that the impact of Brent crude oil price is almost same on selected hub prices. The increasing of Brent price about 1 USD/barrel results to increase TTF price about 0.17 EUR/MWh. The error correction element value is 0.044 which means that every time period deviation from long term equilibrium decreases by -4.4%. In our case this period is one day, which means that this correction is appropriate.

### 3.2 Relationship between crude oil and natural gas prices on American market

As we mentioned in the beginning, situation on American market is different than in Europe. The determinants which influence natural gas prices are different, change of natural gas prices also depending mainly on two important factors; the future rate of macroeconomic growth with consumption in North America and the expected cumulative production of shale gas wells over their lifetimes. Shale gas production and exploration of new resources of unconventional gas should push the prices down, regardless of developing of crude oil price.

The analysis will focus on relationship between WTI crude oil spot price and natural gas spot price on Henry hub in Louisiana. Due to its importance, it lends its name to the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX). WTI price are stated in USD/barrel and natural gas is denominated in USD/mmbtu (millions of British thermal units). We are using monthly data for period from January 1982 to January 2013 (figure 2). Data are obtained from U.S. Energy Information Administration (EIA).

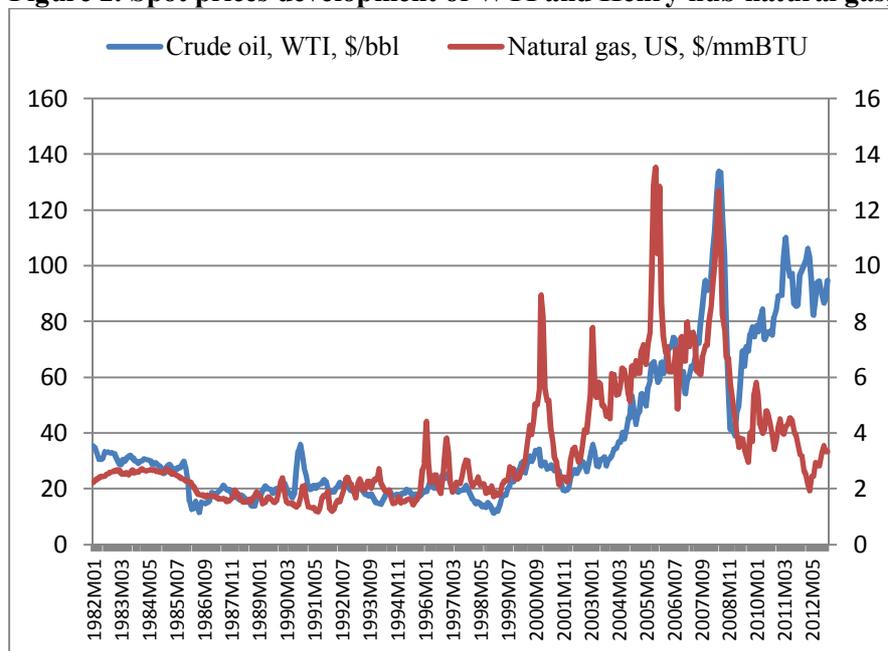
#### Granger causality test

Since the fluctuated development of natural prices gas at Henry hub we have tested the causality between the selected variables in three periods (table 3). We assume that causality will not run from both sides in all periods, but in some of selected periods from WTI to natural gas price. In the same time we have assumed that causality direction from natural gas to WTI could be in the last selected period 2011m11 2013m01, when the shale gas production boom occurred.

The results have proved our assumption that price WTI crude oil is not influencing natural gas price during the whole period. As turning point seems to be year 2011, from which causality is rejected for rest period. It can be seen that causality runs from WTI to natural gas to the end of year

2011. It may be because of boom of shale gas production and oversupply on American market. On the other hand we can see that the causality from natural gas prices to crude oil is not confirmed.

**Figure 2. Spot prices development of WTI and Henry hub natural gas, 1982m01 – 2013m01**



Left axis - WTI crude oil price; right axis – natural gas prices on Henry hub  
Source: Own calculation based on EIA data.

**Table 3. Granger Causality test (Null hypothesis: x does not granger cause y)**

Null Hypothesis:	F-Statistic	Prob.
Sample: 1982m01 2013m01		
HENRY does not Granger Cause WTI	1.69165	0.1857
WTI does not Granger Cause HENRY	1.77310	0.1713
Sample: 1982m01 2011m10		
HENRY does not Granger Cause WTI	2.08517	0.1258
WTI does not Granger Cause HENRY	3.09220	0.0466
Sample: 2011m11 2013m01		
HENRY does not Granger Cause WTI	3.01749	0.0943
WTI does not Granger Cause HENRY	1.90812	0.1986

Source: Own calculation in Eviews 6.

These results do not mean that between variables no long run relationship. For this purpose we have tested using ADF test. According to the test results we found that both time series are integrated processes. According to the results of Johansen cointegration test we have established Vector error correction model, to give us answer on long run behaviour between the selected variables. Since the Trace test results have indicated that there is one cointegration equation between variables at the 0.05 significance level, we have established VEC model.

*Vector error correction model*

To take the simplest possible example, consider a two variable system with one cointegrating equation and no lagged difference terms. The cointegrating equation is:

$$y_{2,t} = \beta * y_{2,t} \quad (9)$$

The corresponding VEC model is:

$$\Delta y_{1,t} = \alpha_1(y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t}, \quad (10)$$

$$\Delta y_{2,t} = \alpha_2(y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t}, \quad (11)$$

The error correction models stand for the one period lagged cointegrating equation and the lagged first differences of the endogenous variables. The coefficient  $\alpha_i$  measures the speed of adjustment of the  $i$ -th endogenous variable towards the equilibrium. In the VEC model specification, we determine linear trend and intercept.

In the first part of table (Table 4) there are displayed the estimates of the cointegrating equation, while the second part presents the estimates of the speed of adjustment (to equilibrium) coefficient with their corresponding standard errors and t-statistics. As one can notice from Table 4 (normalized with respect to HENRY), about 5,9% of the disequilibrium is corrected by changes in natural gas prices, while 22.5% of disequilibrium is adjusted by changes of the crude oil price.

**Table 4. Vector error correction estimates for Henry hub prices and WTI**

Cointegration equation 1		
<b>HENRY</b>	1.000000	
<b>WTI</b>	-0.026246	
<i>Standard errors</i>	(0.02858)	
<i>t - statistics</i>	[-2.79888]	
<b>@Trend</b>	-0.019463	
<i>Standard errors</i>	(0.00676)	
<i>t - statistics</i>	[-2.87753]	
<i>c</i>	4.237172	
<b>Error correction</b>	<b>D(HENRY)</b>	<b>D(WTI)</b>
<i>Speed of adjustments</i>	<b>-0.059347</b>	<b>-0.224542</b>
<i>Standard errors</i>	(0.01752)	(0.09474)
<i>t – statistics</i>	[-3.38775]	[-2.37020]

Source: Own calculation in Eviews 6.

In addition, we have to notice, that system may omit some important exogenous variables, such as the weather and storage variables, and this could bias the estimated coefficients.

#### 4. Conclusion

Oil prices are traditionally influenced by more than one factor such as supply, demand, speculation in the crude oil markets, the less predictable factors (political instability hurricanes, tsunami, etc.), the US Dollar exchange rate and other factors like capacity of the so-called downstream sector. Furthermore crude oil as a commodity is influenced by the price of its substitute(s). Since oil price is often much volatilized and affects not only prices of other commodities, which are essential for food, chemical and other industries, but subsequently affects the macroeconomic indicators of oil exporting and importing countries, is indeed a subject of many studies, expert's discussions and analyses. In this paper we tried to determine the causes of high oil prices. So according to our empirical results we find that there is a high negative correlation between the US Dollar exchange rate against EUR and oil price and statistically significant and the coefficient is relatively high. Therefore, our assumption has been confirmed and the results of this study confirm also what the previous studies have shown that the impact runs from US Dollar exchange rate to oil price. In addition to the US Dollar exchange rate, there are other variables that were examined in our structural model which have impact on oil prices. The finding being that the demand side factors have a higher significance in the model than the supply side factors. However, in spite of that, the OPEC quotas (DQOATAS) seem to be statistically significant, but there is a positive correlation with oil price, which is not in line with our assumption. This result could be interpreted so that the change of OPEC quotas has not the impact on oil price, because of the often low level of OPEC's compliance (Cheats). On the other hand, US commercial stocks, OECD stocks as well as the OECD strategic reserve as a whole seem to be significant and have a negative correlation with oil price. The increase of stocks of the key oil consumption countries leads to a decrease of the global demand and a drop in the oil prices. In case of GDP growth indicators, they showed to be significant only for China and USA – the two largest

countries in oil consumption. While the GDP growth of China has a positive impact on oil prices in time  $t$ , the GDP growth of USA has a positive impact on oil prices, but with three months lag ( $t-3$ ). However, the GDP growth of USA at time  $t$  has a negative impact. This does not correspond with our assumption, since USA is the world's largest oil consumer.

Our empirical evidence also supports the presence of a cointegrating relationship between the crude oil and natural gas price time series, providing significant statistical evidence that WTI crude oil and Henry Hub natural gas prices have a long-run cointegrating relationship. A key finding of the analysis is that natural gas and crude oil prices historically have had a stable relationship, despite period where they may have appeared to decouple. A VECM of crude oil and natural gas prices was estimated, and facilitated the analysis of the long-run cointegration relation and short-run adjustments in prices. The estimation of the model resulted in identifying evidence of a stable relationship between natural gas and crude oil prices. The statistical evidence also supported the a priori expectation that while oil prices may influence the natural gas price, the impact of natural gas prices on the oil price is negligible, though from the demand perspective there is evidence of rising of natural gas demand in expense of crude oil (such heating fuels). This fact could be interpreted that the declining of natural gas prices at Henry hub have led to stabilizing the WTI oil prices, which could not say the same about Brent prices at the European market.

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