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To what Extent Do Oil Prices Depend on the Value of US Dollar: Theoretical Investigation and Empirical Evidence

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1. Introduction

In majority, primary commodity prices are expressed in US Dollar, especially oil prices, not only in the commodity markets but also in many international organizations, for example, in the IMF International Financial Statistics, or in terms of indices based on dollar prices. As such, oil prices are obviously affected by inflation as well as real developments, and also by the value of the US dollar exchange rate. Therefore, a change of both variables affects the international trade of all economies. In the case of oil prices, any change of them affects prices of other primary commodities, products and services, and subsequently macroeconomic indicators of oil exporting and importing countries. There is therefore a definite link between monetary policies and exchange rates among other factors and oil prices. And this is the subject of analysis in this chapter.

The oil prices have signed a clearly fluctuated trend starting with the first through the second oil shock up to the present. According to Jalali-Naini &Manesh (2006) the crude oil price exhibits a high degree of volatility which varies significantly over time. Between 1987–2005, oil price volatility far exceeded that of other commodity prices. Behind that, there were many causes – the often mentioned one in the economic and energy-economic literature is the political (war conflicts) instability factor and subsequently the interruption of oil production or supply. It is clear that there are other factors influencing the oil prices – in the last decade, the increasing demand for oil in the emerging economies (China, India etc.), speculation in commodity markets and the weakening of the US Dollar.

The main objective of this chapter is to examine the correlation between oil prices and the value of the US dollar (USD), and to draw some conclusions about the oil market. Considering that one of the causes of raising the oil prices is a drop of the value of US dollar, to what the extent the US dollar declined we will see via its exchange rate against the main currencies like Japanese (yen), and other European currencies and the subsequent impact on the oil prices.

In addition to the qualitative analyses, as the research method we are using regression model, financial models, Granger causality and structural models to identify to what the

extent the oil prices depend on the value of US Dollar, as one of the factors influencing the oil prices in the international markets, particularly in the last two decades.

The chapter is organized as follows. Section 2 presents some theoretical investigations and discusses the existing literature. Section 3 qualitatively and statistically analyzes the development of oil prices in nominal and real terms since 1970. Section 4 tries to analyze the development of the US Dollar exchange rate with relation to oil prices. The empirical analyses as well as econometric modeling of oil prices and its results are presented in Section 5.

2. Theoretical investigation and literature discussion

Traditionally, behind the increase or drop of oil prices is 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, tsunami, 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. In this chapter we will devote more attention to the role of movement of US Dollar exchange rate in the movement of oil prices.

Many studies related to this issue have been done. Part of them, 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" (Coudert, Mihnon & Penot, 2008). In the same link (Amano & 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 behavior" (Amano & 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 & 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.
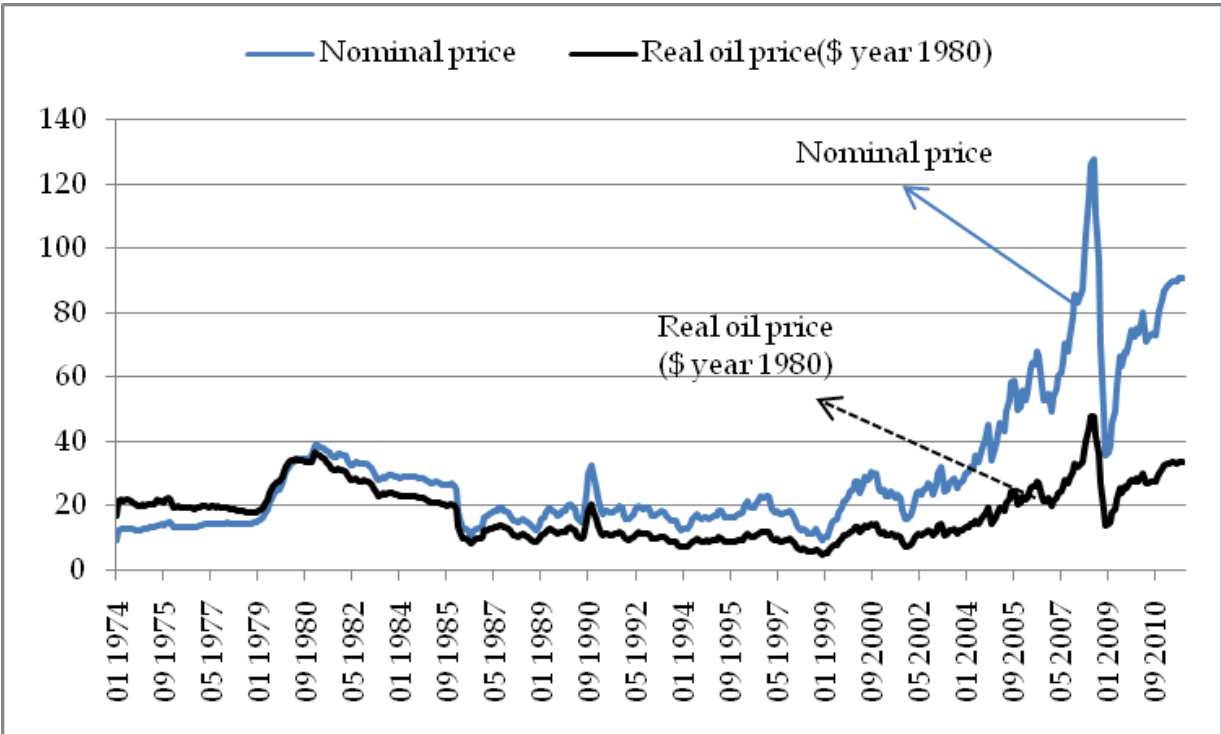
In the same link, Krichene (2005) examined the relation between oil prices, interest rates and US Dollar exchange rate NEER. In his study the attention was given to shocks arising from monetary policy—namely, shocks to interest and exchange rates. He used a vector autoregressive model (VAR) to analyze 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).

3. The development of nominal and real oil prices since 1970

The oil prices in the international oil markets have undergone tremendous changes since 1970. Starting from the renegotiation of the „posted price" – a reference price on which royalties to host countries were calculated – in 1970. Before that, this price was fixed (at 1.80 US dollar a barrel during the 1960s) by the major international oil companies that operated the oil concessions in these countries. Subsequent events culminating in the 1973 oil price shock and the eventual transfer of property rights to the host countries heralded the start of a new era in the oil industry (see Obadi, 1999). Middle Eastern countries – through their role in the Organization of the Petroleum Exporting Countries (OPEC) – were at the center of the transformation of the market since they owned the bulk of world proven crude oil reserves. In addition to transforming their societies through the inflow of substantial amounts of oil revenue, the Middle Eastern and North African (MENA) countries encountered new challenges in the area of economic policy and management, including how to cope with the adverse impact of the variability of oil prices on growth (see Bright E. Okogu, 2003).

When we compare the real (Nominal prices are measured in U.S. dollars per barrel. Real oil prices are calculated by Energy Information Agency-EIA, based on constant 1980 prices, and the deflator is consumer price index -CPI of USA based on data from the U.S. Department of Labor Bureau of Labor Statistic) and nominal oil prices (see Figure 1), we can say that the difference varies from one decade to another. For example in the 80s the difference between both average prices is about 4.47 US Dollar/barrel, while in the 90s it is 7.83 US Dollar/barrel. And in the first decade of the present century it is 26.32 US Dollar/barrel. That means that the value of US Dollar has sharply fallen against other world currencies at least in the last two decades. In other words, if the US Dollar had retained its

value it had in 1980, the barrel of crude oil would have cost about 34 US Dollars in October 2011.

Source: author´s calculation based on EIA data, January 2011.

Fig. 1. The development of nominal and real oil prices, 1974-2010.

4. The historical exchange rate of US Dollar and oil prices

The devaluation of the US dollar began on December 18, 1971 continued through early 1972 and culminated in the global collapse of and heightened capital flight from the American unit, induced by the official burial of the two-tier gold market in November and the quadrupling of oil prices in 1973 (Historical Exchange Rate Regime of the United States of America. http://intl.econ.cuhk.edu.hk/exchange_rate_regime/index.php?cid=30) . Eventually, in April 1978, the par value of the US dollar in terms of gold and SDRs was repealed and the US dollar became a floating Effective Rate. The US dollar subsequently found strength in most exchange centers because of high interest rates; lower inflation and foreign capital flowed into the United States.

During 1986 and early 1987, America's unit was again battered in major exchange centres as Washington and the Group of Seven felt that a weak US dollar was the best course for world monetary peace. However, the free markets seemed to think otherwise, constantly pushing the US dollar up in 1988, 1989 and 1990, despite official efforts to keep it weak at a cost of billions of US dollars to the Federal Reserve (see also C K Liu, 2005).
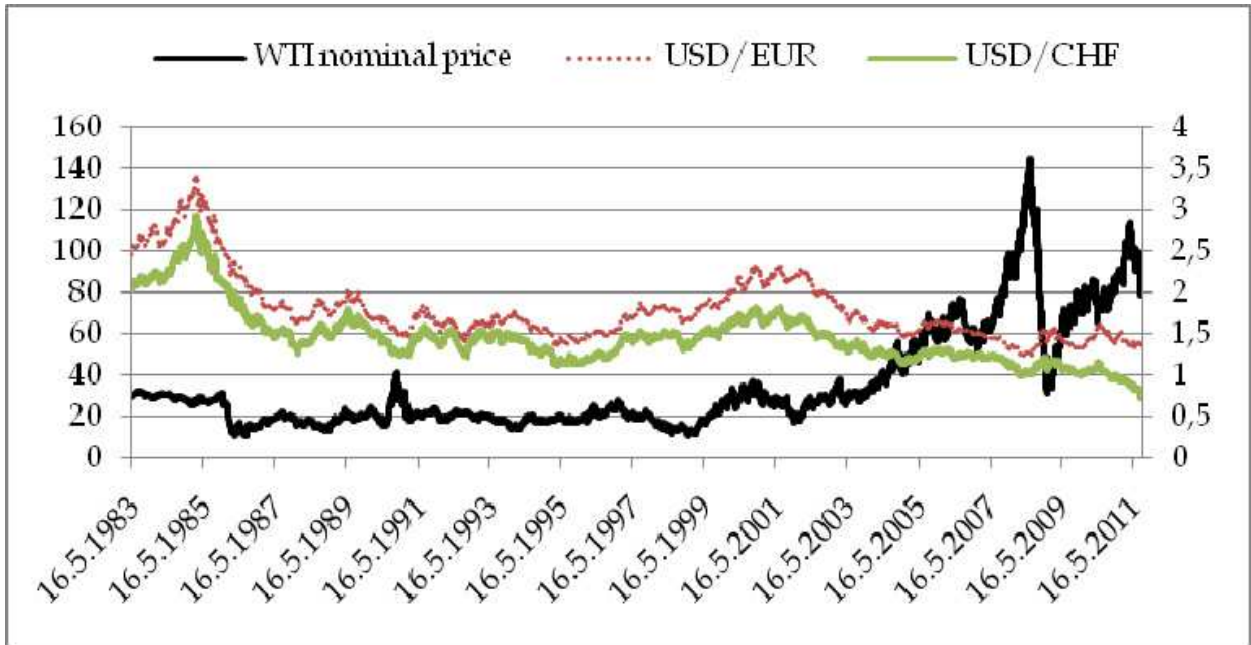
US Dollar against world currencies

Since the 1970s, the two most important currencies, besides the dollar, have been the German mark and the Japanese yen (Mundell, 2003). The dollar has gyrated against other major currencies. Against the DEM, for example, the dollar was DEM 3.5 in 1975 and

decreased in half to DEM 1.7 five years later, in 1980. Then the dollar doubled to DM 3.4 by early 1985, and then fell below DEM 1.35 in August 1992, at the peak of the ERM crisis in Europe. Since that time the dollar has risen far above DEM 2.0 This instability of the USD/DEM rate means that commodity prices in dollars and DEM would be for much of the period moving in opposite directions. In a period when the commodities prices were rising in dollars, they might have been falling in DEMs, and vice versa. The US dollar has lost also much value relative to the euro and the yen (see also Mundell, 2003).

What about the value of the US Dollar against the EUR? Looking to the movement of value of the two largest world reserve currencies during the last 12 years, we could say that it was a dramatic development (see figure 2).Since 2001 to 2011, the US dollar in annual averages lost 36.5% of its value relative to the euro (For the year 2011, the average of daily value of US dollar relative to euro for the period 3.1.2001 - 28.8.2011) when the value of the dollar has fallen from annual average 1.1169 euros to about 0.7095 euros per US dollar.

When the European currency has been launched in January 1999, 862 EUR would have been exchanged for about 1000 US Dollars. However, in February 2002 getting the same amount of US Dollars the Europeans have had to pay more than 1140 Euros – during that period the Euro has fallen sharply, about 33 %. What the EUR has lost during the aforementioned period, it gained again during the period March 2002 –January 2005. The race between these currencies has continued, but with less dramatic development. During the second half of 2005 and the first half of 2006 the US Dollar has gained about 11 % and returned to the approximately same rate it was in 1999. From this period on the US Dollar in average has registered only loses – during the period March 2006 –August 2011 the US Dollar has fallen against the Euro by about 16 %.
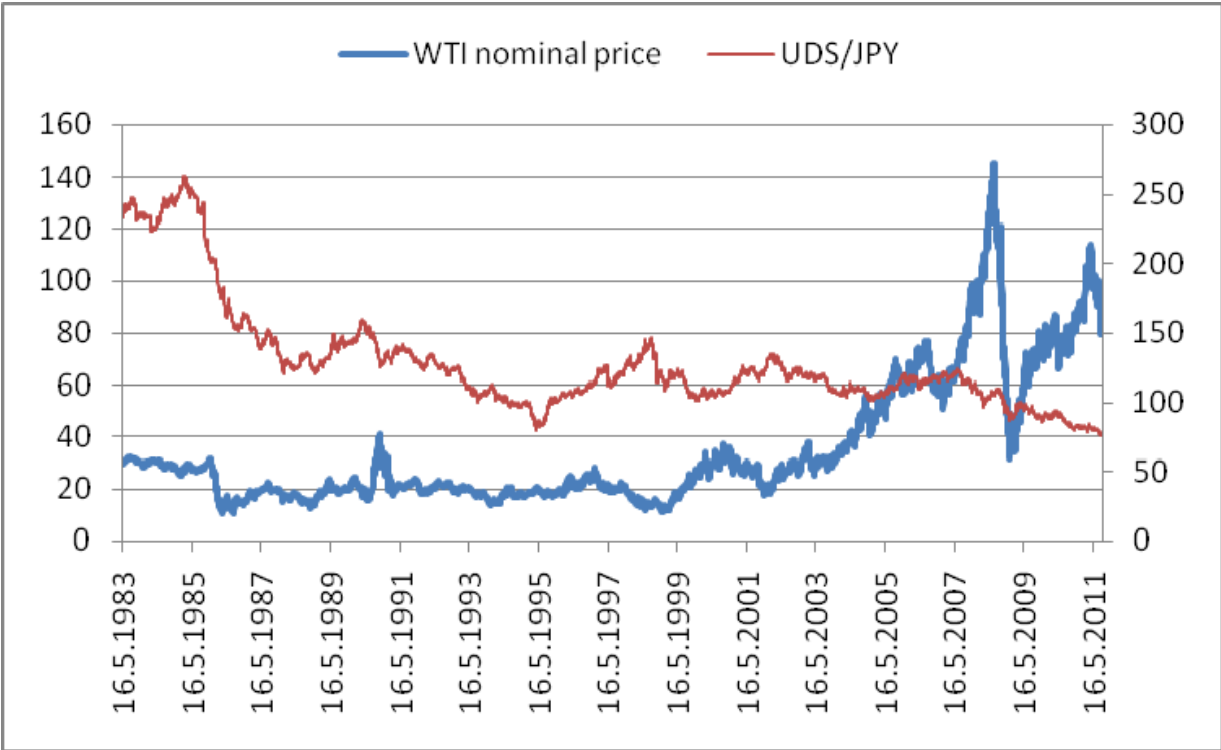

Left axis- oil price WTI in US Dollar and right axis – US Dollar exchange rate against EUR and CHF.
Source: Author's calculation based on data from http://www.economagic.com/ and EIA online data.

Fig. 2. US Dollar exchange rate against EUR and CHF and nominal oil price, 1983 – 2011

In figure 2, the US Dollar exchange rate against EUR is based on the historical US Dollar against Germany currency (DEM) up to the end of 1998. Because Germany is a largest economy in Europe and using a new currency (EUR), since 1.1.1999, it is used in this figure the official conversion rate of DEM/EUR (1 DEM = 0.5113 EUR)

As it is clearly seen in the above figure 2, the development of US Dollar exchange rate against CHF followed an identical trend such as against EUR. This explains the same reaction of the two European currencies to the change of the US Dollar value.

The development of the US Dollar against Japanese Yen was also interesting. Japan maintained a fixed exchange rate of 360.00 yen per US dollar until August 1971. In 1971, the yen was allowed to float above its fluctuation ceiling and an Effective Rate with a fluctuation range was established in December. With continuous devaluation of US dollar, it forced Bank of Japan to place a control on exchange rate, in a floating basis. Afterwards, the Effective Rate of yen was set to be floating freely. Since the introduction of a floating exchange rate system in February 1973, the Japanese economy has experienced large fluctuations in foreign exchange rates, with the yen on a long rising trend. In the same year, another rate called Interbank Rate was set up. The Yen was to be determined on the basis of underlying demand and supply conditions in the exchange markets. The Bank of Japan only intervened in the currency market when the yen fluctuated disorderly. The exchange rate regime was not changed much in Japan (Historical Exchange Rate Regime of Japan. http://intl.econ.cuhk.edu.hk/exchange_rate_regime/index.php?cid=9).

Left axis- oil price WTI in US Dollar and right axis – US Dollar exchange rate aginst JPY
Source: Author's calculation based on data from http://www.economagic.com/ and EIA online data.

Fig. 3. US Dollar exchange rate against JPY and nominal oil price, 1983 – 2011.

"Yen – dollar fluctuations have been just as extreme. In the hey-day of Bretton Woods, the yen – dollar rate was fixed at 360 yen to the dollar. After the 1970s this rate became flexible" (Mundell, 2003). Therefore, the Japanese yen started to rise against US Dollar – during the 1970s gained more than 14 %. During the 70s the US Dollar has lost in value against yen about 43%. During this period both economies have experienced economic slowdown as the consequences of two crude oil shocks. But the Japanese yen has gained a better position relative with US Dollar. During the first half of 80s the US Dollar gained in its value relative to yen again about 23 %. But it was the last time of its gaining in value against yen - by February 1985 the dollar was 260 yen. Ten years later, by April 1995, the dollar had fallen to 79 yen. In other words the yen had tripled in value against the dollar. "This was the period in which the balance sheets of Japanese companies were undermined, and Japanese banks ended up with the non-performing loans that persist in trillions of dollars to this day" (Mundell, 2003). As it is shown in Figure 3, the period from April 1995 up to August 2011, was the most fluctuated period between the dollar and the yen. In 1995, 10,000 Japanese Yen would have exchanged for about 107 USD, but in 2001 the same amount of yen exchanged for only about 82 USD – a close to 30% decline of the Yen (Historical Exchange Rate Regime of Japan. http://intl.econ.cuhk.edu.hk/exchange_rate_regime/index.php?cid=9). Since 1998, the US Dollar exchange rate against JPY has in average a decreasing trend. The US Dollar has lost against JPY during the period 11 August 1998 -1 Jun 2011 about 45 %.
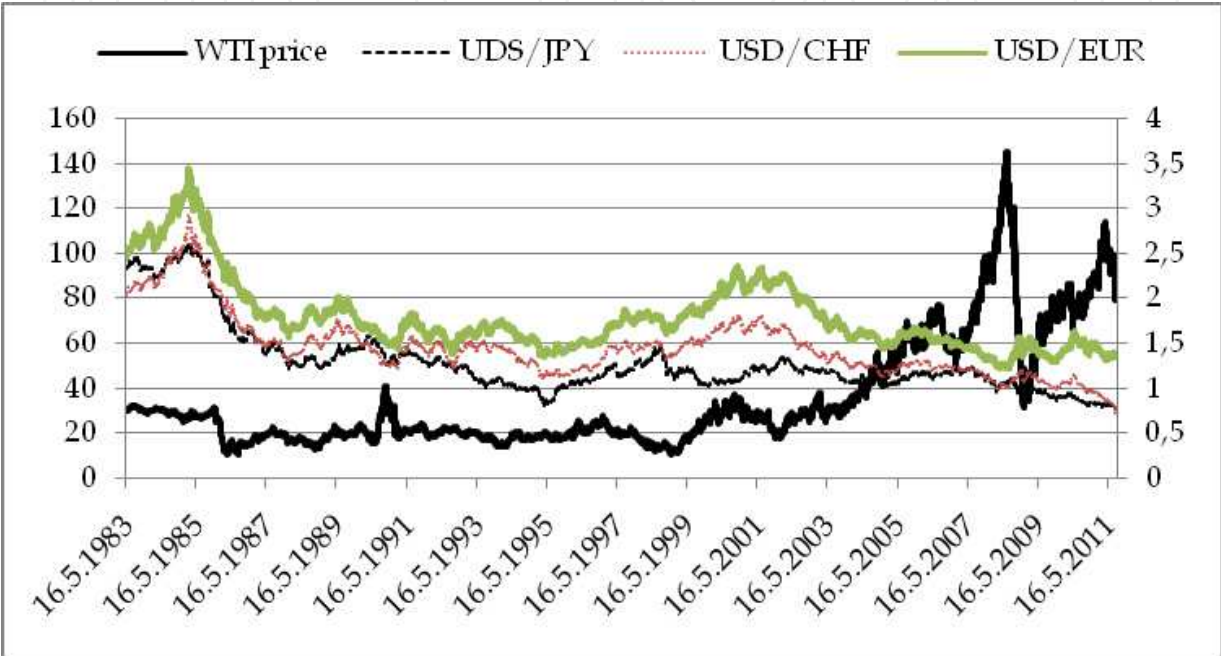
4.1 The US dollar and the oil prices

When we go back to the history of crude oil invoicing by US Dollar, many sources agree that the formation of this idea dates back to 1945, when the US and Saudi Arabia had formed a cooperative partnership, following meetings between Franklin Delano Roosevelt and King Ibn Saud. US oil companies (Exxon, Mobil, Chevron, and Texaco) were already controlling Saudi discovery and production through a partnership with the Kingdom, the California Arabian Standard Oil Company [CASOC, the forerunner of the Arabian American Oil Company (Aramco, the forerunner of today's Saudi Aramco)]. In 1973, the Saudi Government increased its partner's share in the company to 25%, and then 60% the next year. In 1980, the Saudi government retroactively gained full ownership of Aramco with financial effect as of 1976. But, according to research by Spiro (1999), in 1974, the Nixon administration negotiated assurances from Saudi Arabia to setting the price of oil in dollars only, and investing their surplus oil proceeds in U.S. Treasury Bills. In return the U.S. would protect the Saudi regime. At about the same time this was happening (1975), the Saudis agreed to export their oil for US dollars exclusively. Soon OPEC as a whole adopted the rule. Now, as a result, the dollar was backed not by gold but, in effect, by oil. In 1973, with the dollar now floating freely, the Arab nations of OPEC embargoed oil exports to the US and other western countries in retaliation for American support for Israel in the Ramadan/Yom Kippur War. By this time it was clear that US oil production had peaked and was in permanent decline, and that America would become ever more dependent upon petroleum imports. As oil prices soared 400%, the US economy and other Western economies sharply turned down.

"In any case, the oil shock created enormously increased demand for the floating dollar. Oil importing countries, including Germany and Japan, were faced with the problem of how to earn or borrow dollars with which to pay their ballooning fuel bills. Meanwhile, OPEC oil

countries were inundated with oil dollars. Many of these oil dollars ended up in accounts in London and New York banks, where a new process – which Henry Kissinger dubbed „recycling petrodollars" – was instituted" (Heinberg, 2004)..

OPEC countries were receiving billions of dollars they could not immediately use. When American and British banks took these dollars in deposit, they were thereby presented with the opportunity for writing more loans (banks make their profits primarily from loans, but they can only write loans if they have deposits to cover a certain percentage of the loan- usually 10% to 15% (Heinberg, 2004).

Left axis- oil price WTI and right axis – US Dollar exchange rate against the selected currencies (the value of JPY is divided by 100)
Source: Author's calculation based on data from http://www.economagic.com/ and EIA online data.

Fig. 4. US Dollar exchange rate against world currencies and nominal oil price, 1983 – 2011

Henry Kissinger, an advisor to David Rockefeller of Chase Manhattan Bank, suggested the bankers use OPEC dollars as a reserve base upon which to aggressively „sell" bonds or loans, not to US or British corporations and investors, but to Third World (developing) countries desperate to borrow dollars with which to pay for oil imports. By the late 1970s these petrodollar debts had laid the basis for the Third World debt crisis of the 1980s (after interest rates exploded). Most of that debt is still in place and is still strangling many of the poorer nations. Hundreds of billions of dollars were recycled in this fashion. (Incidentally, the borrowed money usually found its way back to Western corporations or banks in any event, either by way of contracts with Western construction companies or simple theft on the part of indigenous officials with foreign bank accounts) (Heinberg, 2004).

Also during the 1970s and '80s, the Saudis began using their petrodollar surpluses to buy huge inventories of unusable weaponry from US arms manufacturers. This was a hidden subsidy to the US economy, and especially to the so-called Defense Department. With the end of Bretton Woods in 1971, the US refused to continue supplying gold at 35 US dollars per

ounce to other central banks. There was a December 1971 Smithsonian extension of the exchange rate peg system, with the final breakdown of the fixed exchange rates occurring in March 1973 (McCallum, 1999). The US inflation rate was left to increase dramatically since other countries were no longer locked into supporting the fixed US dollar gold price, or the exchange rate peg, and did not have to buy the excess US dollars. This provides a monetary explanation for the jump in inflation in 1974. Further jumps in the inflation rate in the 1970s occurred during the increasing deficits and money creation of the Carter Presidency, and before the US Federal Reserve tenure of Paul Volcker.

Some literature suggests that US-generated inflation was the main reason for the two „oil shocks" in 1974 and 1979. (Penrose, 1976) mentions that early attempts to raise the oil price were defended by OPEC with the explicit argument to offsetting the cumulative effect of US inflation, as well as to shelter against future erosion of revenues due to inflation (see Gillman & Nakov, 2001).

Similarly, Spero & Hart (1997) suggest that the increasing inflation rate and the devaluation of the dollar lowered the real value of earnings from oil production and led OPEC countries to demand a substantial increase in the price of oil. Barsky and Kilian (2000) question the extent to which oil shocks played a dominant role in triggering stagflation in the 1970s. They argue that there is little evidence that oil price rises actually raised the deflator, and suggest that monetary fluctuations can explain the variation in the price of oil and other commodities.

However, looking at the above figures and both the curve of oil prices and that of the US Dollar exchange rate, we can see a nearly identical trend of US Dollar exchange rate at least against the two selected European currencies, which have in the long term on average a decreasing trend. On the other hand, the oil prices also in the long term on average have an increasing trend (Obadi, 2006). This confirms the fact that the oil prices which are quoted in US dollar depend on the development of its value. The question needs to be asked whether the cycle of the value of the dollar against major currencies is related to the cycle of the dollar oil prices. A casual reading of the statistics suggests that this relationship is quite close. For further illustration, see the empirical section of this chapter, in which we tried to reveal the negative correlation between oil prices and the US dollar exchange rate.

The above figure shows the development of the value of dollar against selected world currencies (JPY, CHF and EUR) and the oil prices since 1983 to 2011, wherein an unambiguously reverse direction of oil prices and the exchange rate of US dollar against the selected world currencies is shown. Similar results had found (Weller & Lilly 2004) – oil prices have risen, while the dollar has simultaneously plummeted against the euro. The authors measured how much these two prices move in tandem, using a correlation coefficient. The correlation coefficient between oil and dollar is –0.7. That is, most of the time, when the dollar fell against the euro, oil prices rose.

OPEC is worried about the weakening value of the dollar: it has lost one-third of its value in just under two years (Rifkin, 2004). Since OPEC sells oil for dollars, the oil-producing countries are losing fortunes. The revenues just as the value of the dollar are diminishing (Obadi, 2006). And because oil-producing countries then turn around and purchase much of their goods and services from the EU and must pay in euros, their purchasing power continues to deteriorate. It is a big factor, perhaps bigger than the global demand and

supply. In the late 1970s, the price of oil increased by 43% in USA but only 1% in Germany and 7% in Japan. That's despite the fact that Germany and Japan were more dependent on imported oil than USA.

5. Oil price in the econometric models

5.1 Methodology

Many 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.

Hamilton (2003) and 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. 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.

Financial models

Financial models are directly inspired by financial economic theory and based on the Market efficiency hypothesis (MEH). This theory is often attributed to Eugene F. Fama whose study "The Behavior of stock market prices" (Fama 1965) is considered crucial in the theory of market efficiency. He says that in the presence of full information and a large number of rational agents in the market, current prices reflect all available information and expectations for the future. In other words, the current prices are the best estimation of tomorrow's prices.

Generally, financial models examined the relationship between the spot price S_t and the future price F_t with maturity T. They examined, whether the future prices are unbiased and efficient an estimator of spot prices.

Reference Model looks like this:

$$S_{t+1} = \beta_0 + \beta_1 F_t + \varepsilon_{t+1} \tag{1}$$

In this equation F_t is an unbiased estimator of future prices S_{t+1}, when common hypothesis $\beta_0=0$ and $\beta_1=1$ is rejected and at the same time we do not indicate any autocorrelation between residues. Chernenko and Schwartz (2004) tested the validity of MEH, focused on the relationship between the difference of spot and future prices. Their model looks as follows:

$$S_t + S_{t+T} = \beta_0 + \beta_1 (F_t - S_t) + \varepsilon_{t+1} \tag{2}$$

They analyzed monthly WTI oil prices in the period from April 1989 to December 2003. The/other authors have also compared the model with a random walk model and showed

that both models exhibit nearly the same accuracy predicting future prices, and also confirmed the theory of market efficiency.

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, Zyren and Shore 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:

$$S = \beta_1 + \beta_2\, OQ + \beta_3 OV + \beta_4 RIS + \beta_5 RGS + \beta_6 DN + \beta_7 D90 + \varepsilon \qquad (3)$$

Where:

OQ is fixed production quota issued by OPEC, the OV is overrun of this quota, 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 1st 1999. Thereby, we obtained a consistent time series for the entire period.

	WTI	USD/EUR	USD/JPY	USD/CHF
Mean	35.86751	0.797079	118.0403	1.375751
Median	22.49	0.764905	117.27	1.3873
Maximum	145.31	1.2089	202.7	2.094
Minimum	10.25	0.570355	76.55	0.7208
Std. Deviation	26.12138	0.135684	19.52577	0.218743

Table 1. Basic descriptive statistics of the selected variables.

Overall, we have 6689 observations for this time period. As the dependent variable we have selected WTI crude oil price. The value of the variable WTI represents the average spot price of WTI crude oil with Incoterms standard FOB (Free on Board), expressed in U.S. dollars for barrel. Correlation between oil prices and the selected exchange rates will be examined through correlation matrix; - the results are shown in Table 2.

	WTI	USD/EUR	USD/JPY	USD/CHF
WTI	1	-0.1916	-0.5053	-0.6960
USDEUR	-0.1916	1	0.2630	0.6813
USDJPY	-0.5053	0.2630	1	0.7233
USDCHF	-0.6960	0.6813	0.7233	1

Table 2. Correlation matrix.

According to this results 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 results of the test we show in table below:

Variable	Intercept/Trend	Lag length	ADF statistic	Significance[1]
WTI	None	33	-0.274031	
D(WTI)	None	32	-12.97032	***
USD/EUR	None	0	-1.095342	
D(USD/EUR)	None	0	-82.28953	***
USD/JPY	None	15	-1.754621	*
D(USD/JPY)	None	14	-19.54761	***
USD/CHF	None	1	-1.873186	*
D(USD/CHF)	None	0	-83.14117	***

[1]Rejecting the null hypothesis on significance level: 10% - * ; 5% - ** ; 1% - ***

Table 3. Results of ADF test.

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 are going to use 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 purpose of the cointegration test is to determine whether a group of nonstationary variables is cointegrated or not. We carried out Johansen cointegration test. This test reports the so-called trace statistics and the maximum eigenvalue statistics. The output of Johansen test also provides estimates of the cointegrating relations β and the adjustment parameters α_{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. If the probability of Trace statistic eventually maximum Eigenvalue statistic is lower than 5%, we accept the alternative hypothesis of cointegration between variables. And therefore we can further examine the longterm relationship among these variables. The results are shown in tables below:

Trace test	No. of cointegration equations	Trace statistics	Probability
	None	6.678723	0.6153
	At most 1	1.39672	0.2373
Maximum eigenvalue test	No. of cointegration equations	Max Eigen statistics	Probability
	None	5.282002	0.7059
	At most 1	1.39672	0.2373

Table 4. The results of trace and the maximum eigenvalue statistics (WTI, USD/EUR).

Trace test	No. of cointegration equations	Trace statistics	Probability
	None	22.95825	0.0031
	At most 1	1.162411	0.281
Maximum eigenvalue test	No. of cointegration equations	Max Eigen statistics	Probability
	None	21.79584	0.0027
	At most 1	1.162411	0.281

Table 5. The results of trace and the maximum eigenvalue statistics (WTI, USD/JPY).

Trace and maximum eigenvalue test results (Table 4) indicate 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.

Trace and maximum eigenvalue test (Table 5) indicates 1 cointegrating eqn(s) at the 0.05 level. So between WTI price and exchange rate USD/JPY there is a long term equilibrium relationship. After the confirmation of a cointegration relation between variables we can establish 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 cointegration term and it is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments.

The basic specification of EC model looks as follows:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_{t-1} + \alpha_{ec}(y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + \varepsilon_t \tag{4}$$

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

Coefficients of EC model between WTI and USD/JPY are stated below:

Adjustment Coefficients			Cointegrating Coefficients	
α_0	α_1	α_{ec}	β_0	β_1
-0.0185	-0.01343	-0.0008	0.026586	0.059388

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:

$$\Delta WTI_t = -0.0185 - 0.1343 \Delta USDJPY_{t-1} - 0.0008(WTI_{t-1} - 0.026586 - 0.059388 USDJPY_{t-1}) + \varepsilon_{t.} \tag{5}$$

Johansen Cointegration test for WTI price and Exchange rate between US dollar and Swiss franc:

Trace test	No. of cointegration vectors	Trace statistics	Probability
	None	15.49471	0.0213
	At most 1	3.841466	0.3892
Maximum eigenvalue test	No. of cointegration vectors	Max Eigen statistics	Probability
	None	17.16444	0.0169
	At most 1	0.741539	0.3892

Table 6. The results of trace and the maximum eigenvalue statistics (WTI, USD/CHF).

Trace and maximum eigenvalue test (Table 6) indicates 1 cointegrating equations at the 0.05 level. So between variables there is a long term relation. We investigate this relation using ECM.

Coefficients of EC model are stated below:

Adjustment Coefficients			Cointegrating Coefficients	
a_0	a_1	a_{ec}	β_0	β_1
-0.0275	-0.00971	-0.06069	0.044751	6.250402

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%.

$$\Delta WTI_t = -0.0275 - 0.00971\Delta USDJPY_{t-1} - 0.06069(WTI_{t-1} - 0.044751 - 6.250402 USDJPY_{t-1}) + \varepsilon_t \quad (6)$$

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:

$$WTI = \beta_0 + \beta_1 OECD + \beta_2 US + \beta_3 CHINA + \beta_4 OECDSTOCK + \beta_5 USSTOCKS + \beta_6 USCOM + \beta_7 WP \; \beta_8 QUOTAS + \beta_9 CHEAT + \beta_{10} GDPGROWTH + \beta_{11} OECDDAYS + \beta_{12} USEXCHANGE + \beta_{13} DUMMY + \varepsilon_t \quad (7)$$

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 **OECDDAYS** 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.

5.2 Results

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. The result of test is stated in table below.

Variable	Intercept/Trend	Lag length	ADF statistic	Significance[1]
WTI	None	2	-0.566609	
D(WTI)	None	1	-6.407248	***
LOG(WTI)	Intercept, Trend	2	-3.282916	*
OECD	None	14	0.215167	
D(OECD)	None	13	-2.450925	***
US	None	5	0.900117	
D(US)	None	4	-11.09349	***
CHINA	None	3	4.535421	
D(CHINA)	None	2	-11.15506	***
OECDSTOCK	None	0	0.848878	
D(OECDSTOCK)	None	0	-13.36523	***
USSTOCKS	None	0	1.645177	
D(USSTOCKS)	None	0	-12.55420	***
USCOM	None	0	0.155353	
D(USCOM)	None	0	-13.59005	***
WP	None	2	2.210754	
D(WP)	None	1	-14.35961	***
QUOTAS	None	0	-0.113869	
D(QUOTAS)	None	0	-13.29784	***
CHEAT	None	3	0.476998	
D(CHEAT)	None	2	-9.948083	***
GDP_US	Intercept	12	-3.093607	**
GDP_GER	Intercept	12	-3.180358	**
GDP_JAP	None	13	-2.286409	**
GDP_CHINA	None	13	-4.046799	***
OECDDAYS	Intercept	14	-3.098642	**

[1] Rejecting of null hypothesis on significance level: 10% - * ; 5% - ** ; 1% - ***

Table 7. ADF test.

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 below:

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
OECDDAYS	-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

Table 8. The results of structural model.

From the results (Table 8), 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:

$$LOG(WTI) = 3.6805 + 0.0003*CHINA_t - 0.0869*GDP\_US_t + 0.0346*GDP\_US_{t-3} - 4.0938*10^{-06}*DUSCOM_{t-1} + 5.5681*10^{-05}*DQUOTAS_t - 0.0145*OECDDAYS_t - 0.5644*USDEUR_t + 0.1357*DUMMY \quad (8)$$

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 demad side. In spite of that, the OPEC qoatas (DQOATAS) 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.

6. Conclusion

In this chapter we have tried to answer the question, what is the impact of movement of the US dollar exchange rate against world currencies on the oil prices? In fact US dollar devaluation creates several problems for the world oil industry. The US dollar is the currency of invoicing in global crude oil trade while oil producing countries use other currencies to buy goods and services from different nations. US dollar devaluation leads to a decrease in drilling activity and then oil supply interruption and an increase of the demand of oil in the countries using world currencies other than US Dollar. Furthermore, US Dollar devaluation decreases the purchasing power parity of oil exporting countries, especially if their currencies are tied to the US Dollar. In other words, the devaluation of US Dollar affects the global supply and demand.

Overall, our empirical results find that there is a high negative correlation between the US Dollar exchange rate against EUR and oil price and statistically significant – *P-value* (0.0000) and the coefficient is relatively high (-0.56). 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.

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.

7. Acknowledgements

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