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Oil and Cars: The Impact of Crude Oil Prices on the Stock Returns of Automotive Companies

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ABSTRACT: In this paper we are testing whether the impact of oil prices is different on the overall market and automotive companies. In addition we investigate, if this relationship is nonlinear. For this we use stock return data of US, German and Japanese car companies, and returns of share indices from the same countries as control variables, and Brent crude oil price changes. We first estimate the impact of crude oil on the indices, then clean the indices from these influences, and afterwards estimate the impact on the stocks. For this we are using OLS and EGARCH (1,1). We conclude that in general the car companies‘ stocks do not react more adversely as the overall market to crude oil price increases, while Japanese companies do not show any excess sensitivity at all. German companies tend to be sensitive, and US and German companies are together more sensitive in the more recent time periods.

Keywords: Crude oil; Automotive; Car producers; Stock returns; Regression; Nonlinear
JEL Classifications: G12; G14

1. Introduction

Noteworthy rises in crude oil prices set the whole economies alert and their impact can be felt on the anxiety of public, prices of goods, and also on the performance of the stock markets. The dependency on energy is the key driver that makes all the evolved economies sensitive to crude oil price changes if the crude oil price is over some threshold level. Although many studies have been conducted about relationship between oil prices and various indicators of health of economy, such as, GDP, bond, and stock markets, there is little evidence of how do the stocks of car manufacturers react to these prices. We have chosen car makers as we think that these companies manufacture products, purchase of which is conditioned on the ability of the owner to bear the costs these products later incur. Electric or other utility companies are even more directly hit by the price of crude oil, but the price elasticity to their products is much lower, since their products are needed for everyday existence of the civilization. On the contrary, cars are not as crucial for life, and therefore demand for them may vary based on the expected future costs they will cause to the owners. One of the few empirical evidences implying that car companies actually may be hurt more by the rise of oil prices is given by Kubarych (2005), who just mentions the case of oil crisis caused by the revolution in Iran in 1979. As a result of oil shortage, which was caused by a halt in production of Iranian oil, was a movement of the US investors away from car companies to the energy sector, which despite its large dependency on oil did not show erosion in stock prices. In addition, the US government issued a bail-out for Chrysler by which it actually clearly marked that the car industry is in distress.

We base our study on several previous papers that investigate the impact of the crude oil prices from different perspectives not limiting ourselves only to those investigating the relationship between stocks and oil price so as not to neglect other examples of methodology. Crude oil price has been used by many studies as it is deemed to be one of the few factors determining the state of the economy that is independent on the economy itself. Where other variables are interrelated and the origin of changes is difficult to trace, Hamilton (1985) concludes, that:"…the particular timing of changes in nominal crude oil price reflects largely exogenous development specific to the petroleum sector." Other variables, jointly called as endogenous, such as interest rates, inflation, exchange rates, default spread, etc., have connections one to each other and therefore their use as explanatory variables is always done with a remark to their interdependency. The reason for doing so is, that building a model of the stock price movements based only on exogenous variables is nearly impossible (Jones and Kaul, 1996).

Owing to the abundance of works examining the impact of oil price on stocks, we are now aware of many of its characteristics. One of the characteristics observed by various authors is that reactions to oil prices are not solely dependent on the contemporary oil price change, but it has been proven that lagged prices also possess explanatory power. Sill (2007) uses lagged oil prices for prediction of the GDP growth in the US economy using quarterly data from 1948 to 2005. He found that the oil price is significant for the explanation of the GDP growth, but more importantly, only the lagged oil prices are significant.

A more relevant work, however, is that made by Jones and Kaul (1996) that describe the impact of oil prices directly on stock returns. The results of his work are that there are effects, in most cases detrimental, of oil price movements to the returns of the stocks. In addition, Jones and Kaul (1996) shows that these effects are country specific, what gave us a new dimension that can enrich our study? Importance of past crude oil prices as lagged variables is further characterized as a Granger-cause to the movements in the stock prices. In line with these conclusions goes also a proposition made by Chen et al., (1986) to use vector autoregressive model which would also employ lags of explanatory variables in addition to applying the lags of the dependent variable itself. Although the autoregressive model was in the end actually not used in the paper by Chen et al., (1986) it was mentioned as a relevant way of investigating the issues in question. A confirmation to this, which is of much importance to our methodology, is the paper by Ciner et al. (2002) that was actually using the vector autoregressive model to explore the Granger-causality between stock market returns and oil prices. The importance of this study is not so much in the use of lagged explanatory variables, but in their use on daily data. Before this, Jones and Kaul (1996), and Chen (1986) were using monthly or quarterly data, what made them look on the phenomenon from a macro economical point of view.

Another implication made by Ciner et al. (2002) in his paper about the impact of oil on the equity returns is the non-linear character of this influence. He does so by reinvestigating the paper of Huang et al. (1996) that was looking only for linear linkages.

Employing only the linear relations made him come to a rather striking conclusion that the S&P 500 index actually is not affected by the oil prices. But in other cases there was always observed a reaction of the financial markets with Kubarych (2005) even specifically mentioning the S&P 500. Because of this evidence being contradictory to the one of Huang et al. (1996), Ciner fitted non-linear models on the relationship between stocks and oil and these non-linear models proved to be significant, which will also affect our methodology.

More specific on the non-linearity were Mork (1989) and Hamilton (1996) who stated that the reaction of the stock prices is more sensitive to the oil price increase rather than decrease. This introduces asymmetry into the model which can be caused by particular types of non-linearity. Other papers, such as Bansal and Viswanathan (1993), and Hiemstra and Kramer (1997) also suggest that by asset pricing done only through linear models, other potential aspects of relationship between stock prices and macroeconomic variables are omitted.

Since the data, that we are testing in our paper, is financial data, we will most probably encounter that the residuals of our regression are non-normally distributed, more specifically, heteroscedastic. This notion is also supported by Hayo and Kutan (2005) investigating the effects of oil price fluctuations on the Russian stock markets, who found evidence of ARCH effects in the residuals.

The remainder of this article is organized in the following way. Chapter 2 gives a brief description of the data used, chapter 3 states the goals that we follow in our study, and chapter 4 gives a detailed description of our methodology. The results are summarized in chapter 5 with separate discussion with regards to the main hypothesis of this paper and with regards to the estimated models themselves. Chapter 6 gives conclusion and chapter 8 provides additional insights on the history of oil price developments and justifies our way of division of the data into periods.

2. Data Description

The analyzed data were gained from the DataStream database. Our data range is from 8 Jan. 1982, until 16 Nov. 2007, creating thus 6.746 observations of working days. Regarding time, the data is divided into five periods, as it is described in chapter 8. The data consists of three equity indices, the CDAX, the S&P 500 and the NIKKEI, share prices of six car companies: BMW, FORD, GM, HONDA, TOYOTA and VW, and the Brent crude oil price. Prices are listed as total return indices, except Brent, which was listed in USD.

3. Aim of Study

Given the evidence stated above, this paper tries to investigate the relationship between the car companies' equity returns and the price changes of the crude oil. We would like to confirm or reject the hypothesis, that the automotive firms' stocks are more sensitive to changes in oil prices as is the overall market. Therefore, our hypothesis can be formulated in such a way:

$$H_1 : S_{i,t} > S_{p,t}$$

$$H_0 : S_{i,t} \leq S_{p,t}$$

Where $S_{i,t}$, denotes the sensitivity of the market index in the given time period and $S_{p,t}$ is the sensitivity of the portfolio of car companies in the given time period. By sensitivity we understand the change in the value of index or portfolio given positive change in the price of the crude oil.

In addition, we would like to investigate whether there are differences in this sensitivity among the continents, taking Germany, USA, and Japan into account, where we expect the US companies to be the least sensitive among the three groups. Lastly we will also look for differences between the sensitivity in various periods that we create through the whole time span for which we have available data, that being from 1982 until 2007.

4. Methodology

As the main tool for our research, we use the Ordinary Least Squares method or EGARCH(1,1). In principle there are three components of the model with car company stock returns as the dependent variable, and index returns and Brent crude oil price changes as explanatory variables.

We test six different car companies, grouped into three portfolios. This number of tested companies is very restrictive, but we had to exclude many companies because of data unavailability. For Japan, we were aiming to have the data for the companies with major market capitalization which were Toyota, Honda, and Mitsubishi with the possibility to work also with the smaller companies if no other data was available. These companies are doing business also in other than the automotive industry; therefore we were looking for the data for Toyota Motors, Honda Motors, and Mitsubishi Motors[1]. Out of these three, only Toyota and Honda had data history sufficiently long to compare with the history that we got from other companies, indices, and Brent crude oil. Therefore for Japan, we work with two companies, for which we used total return index (RI) instead of just using the quoted share prices[2]. For Europe we intended to use the shares of the biggest car companies such as Daimler, BMW, Volkswagen, Volvo, Peugeot, and Renault. We omitted Fiat for having the last few years problematic, which wouldn't allow us to regress on this company for all the time periods intended. Out of these companies, only BMW and Volkswagen (hereafter VW) had a stock price history long enough, together with total return index calculated, to be usable for our study. Thus our European portfolio of companies has been reduced only to German companies.

From the US companies the two largest companies were Ford and General Motors. General Motors (hereafter GM) sells its products as Chevrolet, Buick, Saab, GMC, Pontiac, Cadillac, Hummer, Saturn, Opel, Vauxhall, Isuzu, Holden, and Daewoo which makes it presumably the largest car maker of US origin. Of course this company does not sell its products only in the USA, but this is an issue that applies for all major car companies.

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[1] The main source of data was Datastream with having www.econstats.com, www.finance.yahoo.com and www.moneycentral.msn.com as a secondary source of data.

[2] The total return index is more suitable for calculating returns of the particular stock as it indicates the share prices in such a way as if the dividends and distributions were reinvested.

As a result we have created three portfolios of the car companies, having Toyota and Honda as the Japanese portfolio, BMW and VW as the German portfolio and Ford and GM as the US portfolio. Although our aim is not to obtain an asset pricing model with high explanatory power, but only point out the influence of the crude oil prices on the stocks, we still choose to have market indices to serve as control variables in our regressions. Chen et al. (1986) uses indices in their regressions to reflect the impact of the nominal influence of the inflation variables and flow of information into the market. We are aware of the fact that even the indices themselves are influenced by the movements in the crude oil prices, therefore we first run the regressions on Brent for each index and each period. If the influence is significant we adjust the index into such a state, as if it was not influenced by the crude oil fluctuations. This means that if a rise in oil price according to the regression causes a fall in the index value, we back the fall of index by the amount of oil price increase times the regression coefficient. According to the portfolios we created, we have chosen three indices to serve as control variables while aiming at indices aggregating large amounts of companies to truly show the impact of oil price on the whole economy. For the German portfolio, we have chosen the CDAX index, which is an index traded at XETRA exchange in Frankfurt encompassing 684 quotes. For Japan we have chosen NIKKEI 225, and for USA the S&P 500.

The key explanatory variable to our research are the spot prices for Brent crude oil. These prices are, as well as the shares and indices, converted to percentage returns. We use the Brent crude oil for all regressions, including US and Japanese portfolios. We have compared the Brent with West Texas Intermediate crude oil, Cushing, Oklahoma spot price (hereafter WTI) on data ranging from 20th May 1987 until 16th October 2007 and we have obtained a correlation coefficient of 99.7%. Therefore we are convinced that using Brent crude oil prices does not deteriorate our tests performed on the US companies, and we also believe that if there were a crude oil price special for Japan, it would also have to be correlated to the prices of Brent and WTI.

Regarding our model, we are trying to reflect all the empirical evidence that we have documented in the introduction so that we have the broadest possible view on how the oil price can influence car makers' stock prices. Therefore we have created the basic model so that it allows for asymmetric reaction of stocks to oil price fluctuation, and in addition we also test each time if there is an additional need for a non-linear component, although it is obvious that, for example, a quadratic term alone takes care of non-linearity and asymmetry at the same time. The asymmetric reaction is allowed for with inclusion of dummy variables into the model in the same manner as it is done in the GJR model when dealing with asymmetric reaction of stock volatility (Brooks, 2006). We also include lagged terms of Brent oil price changes up to three days into past. We do not use lags of dependent variable as our aim is not to create a perfect model for explaining stock returns, but to enlighten the influence of crude oil on them. Therefore, the basic linear model is following:

$$R_{p,t} = \alpha_1 + \alpha_2 I_{p,t} + \alpha_3 O_t + \alpha_4 O_t{*}D_t + \alpha_5 O_{t-1} + \alpha_6 O_{t-1}{*}D_{t-1} + \alpha_7 O_{t-2} + \alpha_8 O_{t-2}{*}D_{t-2} + \alpha_9 O_{t-3} + \alpha_{10} O_{t-3}{*}D_{t-3}$$

where $R_{p,t}$ is the percentage daily return of the car company portfolio, $I_{p,t}$ is the percentage daily return on the equity index related to the portfolio, O_t through O_{t-3} are the percentage daily changes in the oil price from the day of observation up to three days before, and D t is a dummy variable corresponding to the oil price, while and $D_t = 1$ if and $O_t > 0$ and $D_t = 0$ if $O_t <= 0$. The sequence of steps in our analysis is following:

1. Performing a regression according to the model above for each period and portfolio.
2. Performing a Ramsey reset test for two fitted terms to check for quadratic and cubic non-linearity. If the Ramsey test points out that quadratic or cubic term should be included, we include into the model quadratic or cubic terms for every explanatory variable.
3. Testing for heteroscedasticity with White's test without cross-terms.
4. Testing for ARCH effects with LM-ARCH test for 10 lags. If the White's test points out that the data is heteroscedastic, and ARCH test does not prove ARCH effects, we redo the regression with heteroscedasticity consistent coefficients and covariances. If the ARCH test points at ARCH effects, we redo the estimation using EGARCH (1,1) model. If both tests do not prove any form of heteroscedasticity, we remain with the linear regression.
5. As the last step we eliminate variables with those coefficients that according to the t-statistics are not significantly different from zero.

In case that an ARCH model is used, we always use EGARCH, since we are working with financial data, and the response of volatility to positive and negative shocks has already been proven to be asymmetric. Since we are modeling a long time relationship we are aware of the fact, that shocks to the prices may cause the data to be non-stationary and that this non-stationarity would most probably not be a deterministic one. However, as we are working with changes of the prices rather than with their absolute values, we in this way induce stationarity to the data and thus we can use OLS as the estimation method.

After performing all the regressions, the task is to compare the effects that the crude oil has on the overall market and the car producers. However, very often, the model that explains the effects of crude oil prices on the overall market differs from the model estimated for the car producers' portfolio. Therefore we had to design a comparing procedure for these models. To keep this part straightforward we want to simply compare the effects that a particular crude oil price change will have on both models by substituting this price into all the explanatory variables O_t through O_{t-3}. This can be simply regarded as a state when the oil price is stable through time, with only one occasional change which is otherwise surrounded by zero changes. Letting this one change go into the past will consequently be reflected in all the variables O_t through O_{t-3}. and thus models that have higher absolute value of coefficients attached to these variables will be more sensitive than those with smaller value or those missing some of the explanatory variables. The value that we use as the particular crude oil price change to be substituted into the model is estimated as a simple average of the whole series of Ot variable. We use just this one average in order to be able to compare the sensitivity of the models between periods. This is denoted as $\overline{O_t}$ In addition, for models including dummy variables, we also substitute the variables D_t through D_{t-3}. We know that these variables affect the model only when the change of oil price is positive. Therefore we also calculate an average value which, since the D_t variable has values only 1 and 0, gives the probability of positive oil price change.

The average values of the D variables are denoted as $\overline{D}_t$ through $\overline{D}_{t-3}$. In the end we thus arrive to an expression that can measure the sensitivity in one number which we may then compare. The general expression for explanatory variables to the power of one is following:

$$S_t = \alpha_3 \overline{O}_t + \alpha_4 \overline{O}_t * \overline{D}_t + \alpha_5 \overline{O}_t + \alpha_6 \overline{O}_t * \overline{D}_{t-1} + \alpha_7 \overline{O}_t + \alpha_8 \overline{O}_t * \overline{D}_{t-2} + \alpha_9 \overline{O}_t + \alpha_{10} \overline{O}_t * \overline{D}_{t-3}$$

Pairs of sensitivities, that is, index and company portfolio for particular country and time period, calculated according to the equation above are, in case that $S_{i,t} > S_{p,t}$ tested with one sided t-test. If the probability of this t-statistics is lower than 0,05 we do not reject the H1 hypothesis.

5. Results

We performed 30 estimations, by which we obtained various models explaining the impact of Brent crude oil price on the market indexes and car manufacturers.

5.1. Comparison of sensitivity

Table 1 shows the calculated sensitivity of various models. It is visible that in fact not in all the cases the car manufacturers are more negatively sensitive to oil price fluctuations as we have assumed.

Absence of this relationship is mostly visible in period 1 and period 3. In period 1 the only country where the car manufacturers' stocks suffer if the price of oil increased is the USA which is actually contradicting what we intuitively expect to see in the models concerning the US car companies. However, according to the t-statistics the difference between sensitivity of the market and manufacturers is not significant. Therefore this does not fundamentally contradict what is regarded as a common knowledge that demand on this market is inelastic with regards to the price of oil. Also interesting is that in this period also the whole markets in Japan and Germany do not reflect the oil price at all, as we have not been able to estimate any version of our model that would prove the oil price to have some explanatory power concerning the performance of the whole market.

However period 1 is a period with stable oil prices, and therefore expectations did not assume any significant and long term rise in the prices of energy, what may be the explanation why traders did not pay much attention to the fluctuations of the crude oil price. Furthermore, the increasing usage of nuclear power created more independence from the oil exporting countries and displaced the oil as a source to create electricity.

TABLE 1
Results of sensitivity analysis[5]

	Average change in oil price			0.04%	
	Average value of dummy variables				
	D_t	D_{t-1}	D_{t-2}	D_{t-3}	
	44.81%	44.80%	44.80%	44.78%	
	Period 1	Period 2	Period 3	Period 4	Period 5
Observations	1112	1166	2233	621	1614
	Sensitivity 10^(-8)				
CDAX	0	-1	-570	0	2715
Ger. Average	2024	-2499	-511	-9336	1382
Prob.(t-stat)		0,00		0,00	0,00
S&P 500	975	-1344	-141	-1680	7
USA Average	-349	-2423	38	1145	-2186
Prob.(t-stat)	0,1262	0,02			0,00
NIKKEI	0	-3787	-1547	0	0
Japan Average	3135	-3669	-312	-1963	-432
Prob.(t-stat)				0,12	0,14

Note: 5: Periods and countries where we do not reject the H1 hypothesis are in gray color.

In period 2 we observe a behavior that is more in line with our hypothesis. The car company portfolios from USA and Germany show that they reflect the oil price changes in a negative way. This is despite the low crude oil price which is the result of the fight for market share in period 1. Hauptmeier (2007) also contradicts our results stating that the low Brent price benefited the development of SUV's and Vans which had first in the USA a rising demand. During the second period BMW and VW launched cars with bigger engines with great success.

In period 3 the negative impact of oil is evident on all the markets. However according the outcome of our research, although the reaction of car manufacturers to an oil price increase is adverse, except the US manufacturers, it is not worse than the reaction of the market as a whole. On the other hand, in the USA the reaction of the portfolio is in fact the only positive one in this period what we would not expect when looking on other sensitivities in this period. If we had to decide on our hypothesis based on this period, we would without any doubt have to reject it. The highly negative NIKKEI sensitivity value during that period can be explained with the Asian crisis during 1997 and 1998.

If the t-statistics were not implying rejection of hypothesis H1, period 4 could be characterized as the first period when the Japanese manufacturers' stock prices start to reflect crude oil prices. The fact, that also in this period there is not much evidence to prove our hypothesis, except for German portfolio, can be explained so that during this period, car manufactures start to produce cars which use less gasoline. Here, especially the Japanese brands have a major impact on that improvement. Honda for example, produced the first hybrid car which uses energy in a second engine to reduce air pollution and to safe gasoline.

The last period captures the behavior of the stock markets after the terrorist attacks in the USA and consequently also in Europe and Asia. These attacks gave rise to the armed conflicts in Afghanistan and Iraq and have largely increased the tension between the western and the Arabic world. Therefore period 5, apart from t-statistics for Japan, is the only part of our data fully favoring our hypothesis that car industries, due to nature of their products, are affected by movements in oil prices in greater manner than the overall market. As it is shown in graph 1 the Brent price reacts strongly to political events and political decisions. One of the results was the shift of the focus on Diesel engines as well as engines having a smaller volume. We can thus conclude that on average our hypothesis is less prone to be rejected in the last two periods. However in general we have to reject it, since we cannot reject only in five cases from fifteen. From the point of view of countries, German and US automotive industry is according to our results more sensitive to crude oil price changes than Japan, which according to our methodology proves to be insensitive to adverse changes in crude oil prices. When comparing periods, it is interesting to see, that there are two periods, in which the car companies in the three countries investigated seem to be protected from unfavorable impacts of changes in the crude oil prices.

5.2. Estimation of Models

5.2.1. Models of index returns

With regards to the models of indices, the CDAX either cannot be modeled as being related to the crude oil or the models are rather complicated. This point out, that relationship between the German market and the shifts in the prices of crude oil is not straightforward implying that in the German economy, there may be a balance between the companies that are indifferent to the price of oil, companies that are affected positively, and companies that are affected negatively. A prove to this can be also seen in Table 1, where sensitivities of CDAX are less negative compared to those of NIKKEI and S&P 500.

The S&P 500 is the only index that showed to have a relationship to the crude oil prices in all of the five periods. This also points out, that although we are using Brent crude oil for the estimations, this is methodologically correct. It is also noteworthy, that for every period, the S&P 500 includes the current price change at as the explanatory variable. This conforms to our expectations as the US exchanges open later than the European ones where Brent is traded, which leaves enough time to reflect the newest oil price fluctuations. Interestingly, the simplest models are obtained for NIKKEI. It is also interesting to see that for this market only O_t and O_{t-1} serve as the explanatory variables. The logic would however imply that since the Japanese market is ahead of the European, O_t as the current price change should not be reflected in the models, or the place value of the coefficient should be smaller. However, in period 2 where both O_t and O_{t-1} are present, the coefficient for O_t is -0,03 and for O_{t-1} it is -0,06. This shows some dominance of the lagged variable, but not as obvious as we would expect. In general the models for index returns obtain very low adjusted R-squared, the highest being only 2%, which, however, does not cast any doubt on our approach as the crude oil cannot be the only explanatory variable that reasons the fluctuations on the overall market (Table 2).

TABLE 2

Overview of index model estimations

	Model	Adj. R^2	DW	Prob. (F-stat)
Period 1				
Germany[6]	0	0.00	1.53	0.09
USA	$0,00 + 0,05 * O_{t-2} * D_{t-2} - 1,80 * O_t^3 * D_t$	0.01	1.83	0.01
Japan	$0,00 - 0,03 * O_t$	0.01	1.79	0.01
Period 2				
Germany	$1,39 * O_{t-1}^2 - 3,29 * O_{t-1}^2 * D_{t-1} + 10,95 * O_{t-1}^3$	0.01	1.54	0.00
USA	$0,00 - 0,03 * O_t$	0.00	1.93	0.01
Japan	$0,00 - 0,03 * O_t - 0,06 * O_{t-1}$	0.02	1.85	0.00
Period 3				
Germany	$0,00 - 0,03 * O_{t-1} * D_{t-1} -1,04 O_t^3$	0.01	1.86	0.00
USA	$0,00 - 0,02 * O_t + 0,01 * O_{t-2} - 0,66 * O_t^3 + 3,61 * O_{t-3}^3 * D_{t-3}$	0.02	1.95	0.00
Japan	$0,00 - 0,04 * O_{t-1}$	0.00	2.05	0.00
Period 4				
Germany	0	-0.00	1.94	0.63
USA	$0,00 - 0,10 * O_{t-1} * D_{t-1} - 23,92 * O_t^3 * D_t + 33,35 * O_{t-1}^3 * D_{t-1}$	0.02	1.97	0.00
Japan	0	-0.01	2.04	0.93
Period 5				
Germany	$0,00 + 0,07 * O_t + 2,93 * O_t^2 - 4,55 * O_t^2 * D_t^2 + 1,04 * O_{t-3}^2 - 1,53 * O_{t-3}^2 * D_{t-3}$	0.01	2.06	0.00
USA	$0 + 1,04 * O_t^2 - 1,26 * O_t^2 * D_t$	0.00	2.07	0.01
Japan	0	-0.00	2.04	3.66

Note: 6: Zero indicates, that the estimated model had Probability of F-statistics was higher than 0,05

5.2.2. Models of portfolio returns

A general trait of all the models of portfolio returns is, that in all of them the indices were included, which fundamentally approves of our design of basic model that we use in our research. With this model we manage to obtain relatively high adjusted R-squared which in period 2 is for Germany as high as 72% (Table 3). The models for the German portfolio consisting from VW and BMW are the most complex ones. One might think that this implies ambiguity in the relationship, or at least in the way we model it, but these estimations obtain the highest R-squared. Except period 4, in which the model for Germany is the only one not to be estimated with EGARCH, all the estimations gain R-squared higher than 55%. It is also worth noting that for all periods, the models include dummy variables and/or non-linear variables. This conforms to previous works that point out that the relationships between oil prices and stock returns are non-linear, where in our case the non-linearity is introduced through square or cubic explanatory variables or asymmetry inducing dummy variables. The US portfolio returns, in contrast to the German ones, are in all the periods modeled in simpler way while absolutely lacking any cubic or square independent variables. The dummy variables are also present only in period 1 and 4. There is however a significant change observable between the periods, where in the first two periods, the adjusted R-squared is above 50%, and afterwards falling to 20-30%. The complexity of the models estimating the returns of the Japanese portfolio varies through time the most. One of the few traits that these models have in common is that they are missing square explanatory variables. Therefore the only asymmetry inducing factor left are the dummy variables, which are present only in period 3 and 5. This therefore does not give much support to the claims of other authors regarding the asymmetry of the stock reactions to crude oil price changes. The adjusted R-squared remain however relatively stable in all the periods, fluctuating around 30%. In general, we can also conclude, that the model estimations were the simplest for the 1st period, as they did not include square or cubic variables, when taking only oil price variables into account. Further on, the models grow more complex, with the exception of the US portfolio.

TABLE 3
Overview of the portfolio model estimations

	Model	Adj. R^2	DW	Prob. (F-stat)	EGARCH
Period 1					
Germany	$-0{,}00 + 1{,}65 * I_{g,t} - 675{,}22 * I_{g,t}^3 + 0{,}05 * O_{t-1} - 0{,}11 * O_{t-1} * D_{t-1} + 0{,}10 * O_{t-2} * D_{t-2}$	0.56	1.95	0.00	yes
USA	$0{,}00 + 1{,}40 * I_{u,t} - 0{,}04 * O_{t-1} + 0{,}08 * O_{t-2} *$ Dt-2	0.51	1.77	0.00	yes
Japan	$0{,}00 + 1{,}39 * I_{j,t} + 0{,}08 * O_t$	0.29	2.12	0.00	yes
Period 2					
Germany	$0{,}00 + 1{,}38 * I_{g,t} - 0{,}07 * O_{t-1} - 1{,}23 * O_{t-1}^2 * D_{t-1} - 2{,}41 * O_{t-2}^2 + 2{,}43 * O_{t-2}^2 * D_{t-2} + 10{,}80 * O_{t-1}^3 - 28{,}47 * O_{t-2}^3 + 28{,}72 * O_{t-2}^3 * D_{t-2}$	0.72	2.16	0.00	yes
USA	$0{,}00 + 0{,}10 * I_{u,t} - 0{,}04 * O_t - 0{,}02 * O_{t-1}$	0.61	1.97	0.00	yes
Japan	$0{,}00 + 0{,}89 * I_{j,t} + 20{,}16 * I_{j,t}^3 - 0{,}04 * O_t - 0{,}06 * O_{t-1} + 5{,}35 * O_{t-3}^3$	0.35	1.82	0.00	yes
Period 3					
Germany	$0{,}00 + 1{,}37 * I_{g,t} - 0{,}03 * O_t * D_t - 2{,}48 * O_t^3$	0.62	1.96	0.00	yes
USA	$0{,}00 + 1{,}02 * I_{u,t} - 0{,}05 * O_t + 0{,}05 * O_{t-2}$	0.29	1.94	0.00	yes
Japan	$0{,}00 + 0{,}65 * I_{j,t} - 0{,}03 * O_{t-1} + 0{,}05 * O_{t-2} - 0{,}08 * O_{t-2} * D_{t-2}$	0.39	1.97	0.00	yes
Period 4					
Germany	$0{,}00 + 0{,}58 * I_{g,t} - 0{,}47 * O_{t-1} * D_{t-1} + 15{,}51 * O_{t-1}^2 * D_{t-1} - 103{,}48 * O_{t-1}^3 * D_{t-1}$	0.17	1.77	0.00	no[7]
USA	$-0{,}00 + 0{,}72 * I_{u,t} - 0{,}12 * O_{t-1} + 0{,}20 * O_{t-1} * D_{t-1} - 0{,}10 * O_{t-3} * D_{t-3}$	0.21	2.46	0.00	yes
Japan	$0{,}00 + 0{,}70 * I_{g,t} - 0{,}05 * O_{t-1}$	0.25	1.81	0.00	yes
Period 5					
Germany	$-0{,}00 + 0{,}94 * I_{g,t} - 0{,}05 * O_t + 0{,}13 * O_t * D_t - 0{,}07 * O_{t-3} + 0{,}21 * O_{t-3} * D_{t-3} - 5{,}96 * O_{t-3}^2 * D_{t-3} - 17{,}24 * O_t^3 + 46{,}09 * O_{t-3}^3 * D_{t-3}$	0.57	2.03	0.00	yes
USA	$0 + 1{,}14 * I_{u,t} - 0{,}06 * O_t$	0.31	2.05	0.00	yes
Japan	$0{,}00 - 0{,}78 * I_{j,t} - 0{,}02 * O_{t-1} + 0{,}03 * O_{t-2} - 0{,}05 * O_{t-2} * D_{t-2} + 0{,}35 * O_t^3 + 0{,}34 * O_{t-1}^3$	0.35	1.92	0.00	yes

Note: 7: For period 4, the estimation for German portfolio was done with Heteroscedasticity-consistent standard errors & covariance

6. Conclusion

The results of the analyses are representing a divided picture of what was assumed. A link between the crude oil price and the price of shares of car producing companies is not given during every period as well as for every portfolio. As it is written above, the impact of the crude oil price can be seen only with the US and German car companies while being absent with Japanese car producers. Therefore we have to reject our assumption that the US car companies are the least sensitive, as it is stated in chapter 3. It is also worth noting, that periods 1 and 3 seem to absolutely reject our hypothesis that the car companies' stock prices are affected in a negative way when oil prices rise. When looking at the results from a global point of view, we can say that our hypothesis is least prone to be rejected for the German car companies and it also gains on significance in the more recent periods, namely the fourth and the fifth. But still we have to conclude, that according to our methodology, we cannot say that on global scale the car companies are suffering more from rising prices of the crude oil as the rest of the economy. Looking at the structure of our estimations of models that describe the reaction of stock price returns to changes in the crude oil price, we can say that this structure conforms to previous work done in the field in the sense that the stocks do react to the changes in the market environment in a nonlinear way, which often causes the reaction also to be asymmetric. Another important finding is that also when investigating daily returns, there is still evidence, that the markets do not react immediately but incorporate the evolution in the crude oil prices only after some time, which conforms to the findings of Ciner (2001).

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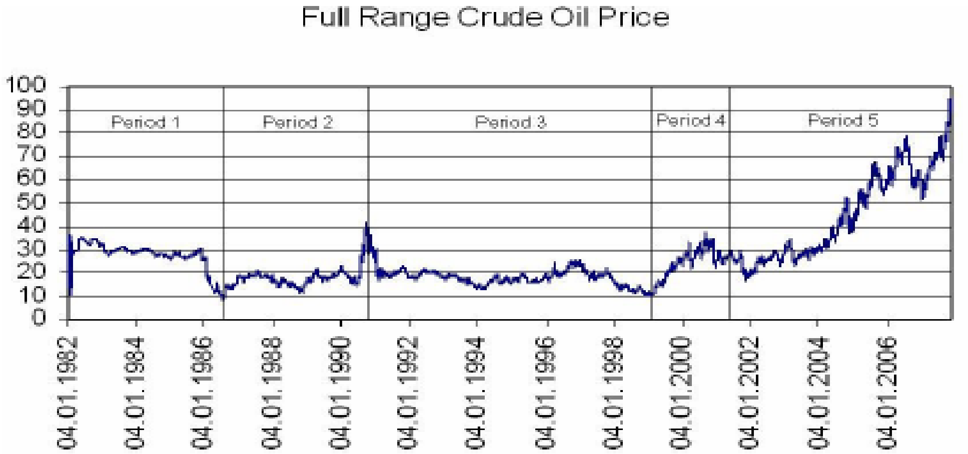
Appendix I
Historical description of crude oil prices

As it is visible from Graph 1, oil price volatility changed strongly during the time. Due to that fact, periods were configured to have oil price changes with relatively stable characteristics and according to geopolitical circumstances. Therefore, 5 periods were created.

GRAPH 1

division of available data into periods



Period 1 (8.1.1982 – 14.4.1986)

The first period starts with a high volatility of crude oil price especially during the first month, later on, the price stagnated at a relatively constant level of \$25 - \$30 and decreased from the 25.11.1986 till the end of the period. This period can be described with an average crude oil price of \$ 28.92, a minimum price of \$ 10.25 on 29.01.1982 as well as a maximum price of \$ 36.1 on 18.01.1982. According to Haskins and Morse (2007), the crude oil price at the first half of the 80's was, compared with periods before, high. This was caused due the fact that non- OPEC production increased whereas OPEC production decreased. Especially Saudi Arabia throttled its production and played a major role within the OPEC. Thus, the total OPEC group output fell from 31.5m bl/d to under 18m bl/d, or from 47% of world production to under 30%. At the same time, non-OPEC states increased their production during the OPEC's decreasing production. As Haskins and Morse (2007) describe, in 1985 Saudi Arabia changed its policy and dropped its former role as swing producer for OPEC and disallowed its main crude stream, Saudi Light, from playing a marker role. After this shift, the OPEC policy was to increase market share, therefore the production got extended. As a reaction of this, the oil price declined down to \$15,5 per bl.

Period 2 (15.4.1986 – 2.10.1990)

During the second period, the oil price had an average price of \$ 17,20 per bl, a minimum price of \$8,75 bl and a maximum price of \$ 41,35 bl. The second half of the 80's presents a low crude oil price. The fight about market share between the oil production countries ended up with a crude oil price of \$ 8,75/bl. According to Haskins and Morse (2007), in the year 1986, the OPEC tried to fix the crude oil price with the help of the USA as well as other oil importing countries by regulating the production. This policy was due to the goals relatively successful. The crude oil prices had an average value of \$17.7/bl in 1987, \$14.3/bl in 1988 and \$17,3/bl in 1989. After the invasion of the Iraq into Kuwait at the 2nd August 1990, the crude oil price increased. Furthermore, production places in Iran were destroyed by an earthquake which explains the period's all time high. The OPEC tried to compensate the oil supply which was throttled in Kuwait and Iraq because of the war. At the same time, the American Petroleum Institute reports a 9m bl draw in US crude oil inventories.

Period 3 (3.10.1990 – 23.4.1999)

The third period's all time high was \$ 41,90/bl, its all time low \$ 9,55, and ist average value during the period was \$ 18,08/bl. In January 1991, the US army launched the first rockets on targets in Iraq. The crude oil price reactions through the US invasion in Iraq were quite abnormal. The Bush administration released, according to Haskins and Morse (2007), US oil reserves to fight a fall in supply and to stabilise the crude oil price, so that the price decreased during the war. As a consequence to the declining oil price and the end of the war in Kuwait, the OPEC cuts its production about 22.3m bl per day. At the same time, the former Soviet Union announced to halve its export because of the low price. As a result, the price rose to $22,5/bl. The following collapse of the Soviet Union however had nearly no impact on the oil price. The years from 1992 to 1996 are mainly coined by OPEC decisions. To push the crude oil price or even fix it at a constant level, the OPEC reduced its production as the overall demand increased. According to Haskins and Morse (2007), the weak oil price after 1997, is mainly caused by the Asian economy crisis from 1997 to 1998. As a reaction, the oil price declined to its period's minimal value at the 21.12.1998.

Period 4 (26.4.1999 – 10.9.2001)

Fourth period's all time high was at the 07.09.2000 with a price of $ 37.64 per bl. Its minimum price was at the 03.06.1999 with a price of $ 14.37 per bl. and an average price of $ 25.62 per bl. This period was chosen as an intermediate between the third period and the last period starting with the attacks on 11.09.2001. It starts with the OPEC agreements to cut production in about 1,7m bl per day. Mainly caused by the OPEC production cuts in March, June and September 2000, the oil price rose until the OPEC decided to increase production. Furthermore, the US government released US oil reserves to stabilize the oil price. This was followed again by an OPEC announcement to increase its production. Until that time, the oil price doubled. In 2001, the OPEC cut its oil production again three times until the terrorist attacks on 11.09.2001 in New York.

Period 5 (11.09.2001 – 16.11.2007)

As it is visible from the graph 1, period 5 can be described with a high volatility of the crude oil price. The period's minimal value is $ 17,15 on 15.11.2001 per bl, ist maximum value is $ 94,88 per bl on 20.11.2007 and the period's average value is $ 46,02. The oil price after the 11.09.2001 is influenced by many political events. After the 11.09.2001, the oil price reacted strongly during the invasion in Afghanistan and Iraq. The war on terrorism in Afghanistan started at 07.10.2001. The oil price decreased because of stabilisation arrangements and the OPEC states. The stabilisation time after the 11.09.2001 can be described as a period of increasing demand and as a result of that, an increasing oil price. During that time, the oil price rose from $42 per bl in August 2004, to $80/bl in July 2007. Haskins and Morse (2007) explain that with 4 main factors. The most important factor is a growth in demand of about 4% during the time from 2004 to 2007. This is due to the economical growth of China as well as the oil demand in the North America. China reached a level of 1/3 usage of the global oil production. As a second cause, Haskins and Morse (2007) mention the limited spare production capacity. Even if Saudi Arabia has increased its oil production, lack of investment to serve the rising demand was experienced with nearly every OPEC state. That had the effect, that the supply-demand balanced got permanently displaced. As a third reason, lack of spare refining capacity is mentioned. The overall capacity of important oil production states like Saudi Arabia is reaching its maximum levels. As a fourth reason Haskins and Morse (2007) mention the supply disruption. This was caused by several events in different states. The Hurricane Ivan for example destroyed large oil production fields in the Gulf of Mexico. Thus, a lag of 1,5m bl per day has to be replaced by other countries.