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The Impact of the Deepwater Horizon Oil Spill on U.S. Drilling Companies

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PREFACE AND ACKNOWLEDGEMENTS

This thesis is intended to provide a new view on the impact that the explosion on the Deepwater Horizon rig had on the drilling companies and can assist in the strategy that the drilling firms can follow in the future in terms of exposure and rig allocation. According to this paper the Deepwater Horizon explosion and the followed oil spill had a negative effect on the share price of the exposed firms, however, companies that had allocated their rigs in different wells suffered less from this event. Thus this paper can be considered as a benchmark for drilling firms to manage the risk that arises from natural and unforeseen disasters.

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ABSTRACT

The purpose of this thesis is to examine the impact of the accident on the Deepwater Horizon rig in the Gulf of Mexico on the stock prices of the U.S. drilling companies. We formed a sample consisting of 11 exposed and 23 non-exposed U.S. drilling companies. By investigating the event and reviewing the existing literature we constructed a framework based on which we analyzed the stock prices of the companies in our sample. Our findings indicate that the event had a significant negative effect on the share price of the exposed companies of our sample for the long-term event period and we were able to confirm the findings of previous studies, indicating that the investors' reaction was delayed. Finally, our results specify that the magnitude of the effect of the event on the stock prices was impacted by the level of exposure to the accident for each company.

Keywords: Financial Risk and Risk Management, Gulf of Mexico, Deepwater Horizon Oil Spill, U.S. Drilling Companies, Event Studies, CAR.

JEL Classification: G14**,** Q54, L25.

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CHAPTER 1 Introduction

On the 20th of April 2010 an industrial disaster took place in the Gulf of Mexico, the well-known Deepwater Horizon Oil Spill, which is considered as the largest environmental disaster and oil spill in the history of the oil and drilling industry. The Deepwater Horizon semi-submersible Mobile Offshore Drilling Unit (MODU) was an offshore drilling rig which was owned by Transocean Ltd. and leased by British Petroleum (BP). It was made to operate in depth of 8,000 feet and drill down 30,000 feet, and at the time of the explosion it was located in the Macondo well, 41 miles off the coast of Louisiana. The explosion that occurred on the Deepwater Horizon rig in 2010 resulted in the sinking of the rig, the death of 11 workers and the contamination of more than 1,000 square miles of the seafloor. Hydrocarbons kept flowing to the sea for 87 days and the well was announced as sealed on 19 September 2010. At that time a total of 4.9 million barrels of oil had escaped into the Gulf of Mexico.

The explosion was followed by a fierce dispute regarding the responsibilities for the accident. A great number of investigations took place in order to explore the factors that caused the disaster. A series of news related to the event played a major role into the reaction of the market to the accident. On September 2011 the U.S. Government issued a report in which most of the blame was put on BP but also Transocean, which owned the rig at the time and the oil field service company Halliburton. Engineers from both Transocean and BP were accused, however, in November 2012 BP pleaded guilty for the loss of the 11 workers and was forced to a four-year government monitoring and was temporarily prohibited from contracting with the U.S. Government. Furthermore, federal agencies have, also, been criticized for their duty in ensuring that the rig was satisfying all the requirements and ensuring its overall safety.

Many disasters that were examined in the past showed a quick reaction of the stock market to the announcement of the event. However, the fact that the explosion in the Gulf of Mexico was followed by a series of announcements and the fact that it took more than 3 months to stop the contamination of the waters caused the market to exhibit a number of shocks after the first announcement. The continuously unsuccessful attempts to seal the well and the temporary adverse regulation of the U.S. Government prohibiting Deepwater drilling were the main reasons of the stock market reaction and for destroying stock market value for the drilling and oil companies.

Most of the studies conducted for the 2010 Gulf of Mexico disaster mainly examine the general stock market reaction to the event (Lee and Gomez 2012; Fodor and Stowe 2012; Heflin and Wallace 2017)**.** The main motivation for this study stems from the fact that there was no existing literature researching the effect on the U.S. drilling companies' share prices and specifically of the companies that were exposed to the event. We aim to show that the U.S. drilling companies active in the Gulf of Mexico (GOM) and the drilling industry in general were impacted by the explosion.

The primary objective of this study is to examine the reaction of the share prices of the U.S. drilling companies to the event. Thus our research question can be stated as *did the GOM oil spill in 2010 impact the share price of the U.S. drilling companies?* To answer this question we split our sample into two value weighted sub-samples of drilling companies. The first sub-sample consists of companies that were active in the GOM at the time of the disaster and were exposed to the event and the second sub-sample consists of companies that had no exposure to the accident. By looking on the reaction of the stock market to the Deepwater Horizon Oil Spill and its impact on the shareholder value this study aims to shed light on the disaster and its effects. In addition, this paper examines whether the exposure to the event had a significant impact to the reaction of the share prices and whether this impact is affected by the level of exposure to the accident. To obtain our results we are going to conduct an event study in order to estimate the cumulative abnormal returns which we expect to be different than zero and negative. The estimated cumulative abnormal returns are value-weighted based on the market capitalization of the companies. For the second part we run an ordinary least squares (OLS) regression to examine whether there is a relationship between the cumulative abnormal returns and the level of exposure to the event. The oil price is used as a control variable as it affects directly the companies' cumulative abnormal returns.

Our results indicate that the event had a negative effect on the stock returns of the exposed companies whereas the companies that had no exposure did not suffer from the consequences of the disaster. In addition, we were able to show that there is an increased need of diversification in terms of contracts for the drilling companies because based on our results the higher the exposure that the companies had to the event the higher the hit they received on their stock returns.

For the remainder of the paper we continue in section 2 with the literature review on event studies and previous papers on oil spills and disasters that occurred prior to the Deepwater Horizon Oil Spill and we reach to our hypotheses in section 3. Then, we describe the event in section 4. Section 5 contains the description of the data sets and the methodology that is used to reach to the results. In section 6 we present and discuss the results that we have obtained from the data. Finally, in section 7 we conclude.

CHAPTER 2 Literature Review

2.1 Event Studies

In order to obtain our results, we conducted an event study. An event study typically examines the effects of an unforeseen event to the stock returns for a sample of firms. Event studies have been used for many years, dating back to 1933 when Dolley examined the impact that stock-splits had to share prices. They have changed through time and have shown increased sophistication the latter years in comparison to the first conducted studies. The methodology that is currently used was first introduced by Ball and Brown (1968), who examined the relation between the annual earnings changes and the annual stock returns, and Fama et al. (1969), which investigated the impact of stock splits announcements on share prices. The event study has been modified since then mainly by Stephen Brown and Jerold Warner (1980; 1985) to incorporate issues for monthly and daily data.

According to MacKinlay (1997) to conduct an event study one needs to start by determining the event that will be examined and identifying the event window. The event window can be considered as the time frame over which the share prices of the exposed to event firms will be analyzed. It typically includes the day of the announcement of the event, but it is larger than the announcement day to allow to research the surrounding period and it expands to multiple days (MacKinlay 1997). Expanding to multiple days also helps to cover for any inaccuracies in the exact announcement day. In that way one is able to capture the whole impact of the announcement of the event to the share price.

After determining the event and the event window, it is necessary to identify the criteria based on which the sample of firms will be created. The inclusion may be restricted by several issues, such as the availability of the data or restrictions regarding the industry in which a firm is a member. The selection criteria are equally important with the event identification, because it is essential to identify the firms that are most probably affected by the event.

The next step includes the calculation of the abnormal returns. According to MacKinlay (1997) these can be derived by subtracting the normal returns of the security from the actual ex post returns over the event window. There is a series of models that can be used to estimate the normal returns and there has been a debate regarding the model which provides the most accurate results. Brown and Warner (1980; 1985) showed that the results of short-term event studies that are based on the Constant Mean Return Model do not deviate from the results of more advanced models. Cable and Holland (1999) provided evidence that there is "a clear preference for the regression-based Market and CAPM models, with the Market Model everywhere valid and dominating the CAPM in all but a few cases". As for the Mean-Adjusted Returns Model and the Market Adjusted Model, they were both rejected, as they performed badly compared to the Market Model. The Market Return Model is used in many cases to control the relationship between the stock return and the market return and assumes a stable linear relation (Bonnier and Bruner, 1989; Lummer and McConnell, 1989; Schipper and Thompson, 1983; Homan, 2006; Small et al., 2007; Ishii and Xuan, 2014).

Following the election of the normal performance model, the next step is to determine the estimation window. The most prevalent practice for the identification of the estimation window is to use the period which occurs prior to the event window. When conducting an event study by using daily stock returns and the Market Model, the variables of the model can be estimated over the 120 days previous to the event, according to MacKinlay (1997). However, most studies use either 180 or 200 trading days for their estimation window. In general, the estimation window does not consist of the event window so that the estimates from the normal performance model will not be influenced by it.

After the estimates from the normal performance model have been obtained, it is possible to calculate the abnormal returns and the cumulative abnormal returns. The final step is to come up with the significance tests of the abnormal returns. It is essential to determine the null hypothesis to show whether the obtained results are statistically significant, which will eventually show if the abnormal returns are indeed affected by the event.

There are tests that are based on standardized returns which could potentially outperform the ones based on non-standardized returns. One of these tests is the standardized cross-sectional test or BMP test that was created by Boehmer, Musumeci and Poulsen (1991). When the event causes extra volatility of the event-period returns the null hypothesis could be rejected too frequently and the use of the BMP test could be the means to dodge those frequent rejections (Boehmer, Musumeci and Poulsen, 1991). As a result, in our analysis we use the BMP test to check whether our results are robust.

The event study literature covers a broad range of events, from financial and economic events to environmental disasters, the last which is the main topic of concern for our study. On the following sections we cover the literature similar to the Deepwater Horizon accident.

2.2 Environmental Disasters

The literature which deals with environmental disasters typically takes two paths of examining the events. In the first approach, a specific event is analyzed, while in the second approach the effect of all the environmental disasters is examined as a whole. There are several examples of papers that examine the effect of certain types of environmental disasters and include the response of the share market to chemical disasters and environmental behaviors (Laplante and Lanoie, 1994; Lorraine et al., 2004; Gupta and Goldar, 2005; Capelle-Blancard and Laguna, 2010), hazardous waste lawsuits (Muoghalu et al., 1990), the impact of tropical storms (Fink et al., 2010) and insurances associated with natural hazards (Froot, 2001).

This study falls in the first group of literature as we aim to analyze the effect of the Gulf of Mexico (GOM) oil spill to the drilling companies' share price. There is extensive literature that is dealing with specific incidents. It includes the nuclear disaster at the Three Mile Island in 1979 (Hill and Schneeweis, 1983; Bowen et al., 1983) and the Chernobyl disaster in 1986 (Fields and Janjigian 1989; Kalra et al., 1993), the destruction of the Challenger Space Shuttle in 1986 (Blose et al., 1996; Maloney and Mulherin, 1998; 2003), the Exxon Valdez oil spill in 1989 (Dekel and Scotchmer, 1990; Mansur et al., 1991), the attack on the World Trade Centre on the 11th of September 2001 (Doherty et al., 2003), the 2004 Boxing Day tsunami (Ramiah, 2013), the eruption of the Icelandic volcano Eyjafjallajökull in 2010 (Mazzocchi et al., 2010) and the 2011 Japanese nuclear disaster in Fukushima-Daiichi (Ferstl et al., 2012; Kawashima and

Takeda 2012). In every case, the financial markets reacted differently to the events, mainly because of the differences in the size of the accidents, the information availability and how rapid the announcements of the accidents became known. Furthermore, there have, also, been cases where there was no significant evidence of abnormal returns resulting from the accidents.

While the financial market reaction to the Three Mile Island nuclear accident, was quite fast, due to the rapid announcements concerning the incident and its severity, there were cases like the Chernobyl incident and the Deepwater Horizon Oil Spill, where the announcement of the event was either delayed, or containing inaccurate estimates leading to a slowed reaction of the markets. In the case of Chernobyl, even though the incident took place on the 26th of April 1986, the accident remained concealed for two days by the government of the Soviet Union until the 28th of April 1986, causing a delayed reaction of the financial markets to the accident. Regarding the case of the Deepwater Horizon oil spill, even though the event was not concealed by the government, there was lack of accurate information concerning the size of the accident and the extent of the spill. The initial estimate that was published the following day of the explosion was revised on the 25th of April, and it took more than 9 days (29th of April 2010) for the financial markets to understand the real impact of the accident. (Friedman and Friedman 2010; Fodor and Stowe 2010)

The literature shows that the reaction of the financial markets to certain events is rather selective. Both papers of Fields and Janjgian (1989) and Kalra et al. (1993) provide evidence on the fact that the share prices of the nuclear utilities received a greater hit from the Chernobyl nuclear-power accident. The same results hold for the Three Mile incident according to Hill and Schneeweis (1983) and Bowen et al. (1983), who also find results that indicate that nuclear utilities had greater abnormal returns than the non-nuclear utilities. Finally, regarding the case of the crash of the space shuttle Challenger the reaction of the financial markets was even more focused to the manufacturer that was responsible for the faulty component, which received the whole effect from the accident (Blose et al., 1996; Maloney and Mulherin, 2003).

In 2011 another nuclear accident took place in Japan, after the great earthquake and tsunami, at the Fukushima Daiichi nuclear station. Kawashima and Takeda (2012) conducted an analysis of the event and found that the accident had a negative effect on the stock prices of electric power utilities and mainly on the firm that was hit by the earthquake and the ones that owned nuclear power plants. In particular, TEPCO and Tohoku Electric Power Co. that were hit by the East Japan great earthquake and tsunami suffered a sharper decrease of their stock prices. In another study conducted by Ferstl et al. (2012) the results were similar to those by Kawashima and Takeda. They studied the effect of the disaster on French, German, Japanese and U.S. nuclear and alternative energy stocks and they found that the nuclear energy companies had negative and significant abnormal returns.

The natural disaster that has the most resemblance to the Gulf of Mexico oil spill is the Exxon Valdez oil spill. The oil spill took place in Prince William Sound, Alaska when the oil tanker called Exxon Valdez hit Prince William Sound's Bligh Reef. The reaction of the share market to the event was quite selective, as Mansur et al. (1991) describe, and the share prices that took most of the hit where the companies that were closely linked with the Trans-Alaska pipeline. The aftermath of the Exxon Valdez oil spill included a considerable increase in the prices of gasoline and one could argue that the whole industry might have benefited from the accident. In their study Dekel and Scotchmer (1990) showed that when oil producers share spill clean-up costs, they can maximize profit by colluding and "decreasing incentives for care". However, in the case of the GOM oil spill this argument would not explain the size of the disaster, as BP plc agreed that it would solely meet the clean-up costs after the debate it had with its subcontractors. Thus, since there was no cost sharing, there would be no collusion to profit from the spill.

The Deepwater Horizon Oil Spill was examined by Fodor and Stowe (2010), who analyzed the impact of the accident on the financial securities (ADRs, bonds, options and CDSs) of BP plc. They supported that the stock and options markets reacted slowly to the accident, which can be concluded by the fact that the BP plc share price was decreasing for two months. They supported the increased riskiness of BP that option markets estimated, which was shown by the high levels of the implied volatility of the BP share returns. The increased firm specific risk was also reflected by the options markets, where the bonds' interest rate spreads expanded and the prices on credit default swaps rose dramatically. These transitions were also followed by a huge increase in the trading volume of the stock and the options as well.

However, it is not clear that all the events have an impact on market returns. In a study of the impact on the capital markets from the 2004 Boxing Day tsunami, Ramiah (2013) provides evidence that the event had minimal effects on the market. The main purpose was to examine whether there were abnormal returns due to the tsunami and whether there was an impact on the risks of the industry and market portfolios. The analysis that the author performed included countries that were exposed directly and indirectly to the event. The results that the author obtained were not significant, and even though one would expect the incident to impact the capital markets, the tsunami had no negative effect.

On the following sections we describe our hypothesis and the research question according to our literature review and present and describe the data that is used for analysis. Then, we construct the model on which our analyses are based on and discuss the results of our analysis.

CHAPTER 3 Hypotheses and Research Questions

3.1 Research Questions

The main research question of the thesis is defined as: *how did the GOM oil spill in 2010 impact the share price of the U.S. drilling companies and what was the impact of the exposure on the magnitude of the effect on the companies' share prices?* To begin with, an overview of the events that occurred during the Gulf of Mexico oil spill is composed. The announcements that followed after the event are observed and examined. The economic performance of the drilling companies after the event was crucial for the whole oil industry. Therefore, this thesis can provide a new understanding of the effect of the GOM oil spill that has dominated the news on the economic performance of the drilling firms and confirm the findings of the former studies regarding the accident. Furthermore, it investigates whether rigs concentration in certain geographical area affects the investors' reaction.

The first research question is: *did the GOM oil spill in 2010 impact negatively the share price of the U.S. drilling companies?* In our analysis we look at the stock returns, which is also considered as a key metrics of a company's performance, to examine whether they moved abnormally compared to our benchmark. The second research question is: did the exposure to the GOM oil spill in 2010 impact the magnitude of the effect on the stock prices of the U.S. drilling companies? In our analysis we define as exposure to the event the number of a company's drilling rigs that were actively drilling in the Gulf of Mexico over the total number of the company's owned rigs. Thus, we examine whether there is a relation between the exposure to the events and companies' cumulative abnormal returns following the event.

3.2 Hypotheses

Given the effects of the explosion and the following oil spill on the share prices we have come up with the following three hypotheses:

H_1*: The 2010 oil spill in the Gulf of Mexico has had a significant negative impact on the share price of all the U.S. drilling companies.*

H_2*: The 2010 oil spill in the Gulf of Mexico has had a more significant negative impact on the share price of the exposed, compared to the non-exposed U.S. drilling companies.*

H_3: The larger the exposure to the Gulf of Mexico oil spill is, the larger the stock price hit.

Regarding the effect, we are expecting a negative impact from the event on the U.S. drilling companies' stock prices. The accident and the following announcements could significantly change the drilling companies' expectations of earnings and riskiness and as a result investors are expected to react to this event and bid down the price of the companies' stocks. Furthermore, we are expecting a more negative impact on the stock prices of the exposed U.S. drilling companies in general compared to the non-exposed companies. The level of exposure to the accident plays a critical role to the reaction of the investors to events and as a result we expect the exposure to impact positively the magnitude of the effect, meaning that higher level of exposure would result to a greater effect on the stock prices.

CHAPTER 4 The Event

The explosion that occurred on the rig owned by Transocean Ltd. and leased by British Petroleum plc (BP) was followed by a series of announcements regarding the size of the accident. In table 1 we provide a timeline of the announcements that followed the incident. The oil leak was discovered on the 21st of April and the initial estimate, published by the Coast Guard, regarding the oil spill that was created by the explosion at the Macondo well was a flow rate of 1,000 barrels per day (bpd).

However, 3 days later BP reported a leak of 8,000 bpd. The estimates were going back and forth for a period and on the 28th of April the National Oceanic and Atmospheric Administration (NOAA) estimated that the leak was five times larger than what BP plc initially estimated it to be. Finally, Steve Wereley from Purdue University was supporting that the oil leak was not even close to what was estimated, claiming it to be 70,000 bpd.

Date	News Related to the Event
04/20/2010	Explosion occurred on the Transocean rig.
04/21/2010	Coast Guard reports potential environmental threat of 8,000 bpd.
04/24/2010	Initial estimate by BP plc of 1,000 bpd.
04/28/2010	Revised estimate of oil spill is increased to 20,000 bpd.
05/11/2010	BP, Transocean and Halliburton testify before Congress.
05/17/2010	Steve Wereley estimates a leakage of 70,000 bpd.
06/11/2010	Flow Rate Technical Group estimates leak of 20,000-40,000 bpd.
06/15/2010	Oil pouring into the Gulf is cut off.
09/19/2010	BP officially declares well completely sealed.

Table 1 News Related to the Event

On the 11th of May 2010 the companies that were involved in the incident testified before Congress to determine liability for the oil spill. During the hearing all the parties were shifting the responsibility for the environmental disaster to each other. Both Transocean and Halliburton were putting the blame on BP plc for the accident, whereas BP plc was mainly blaming Transocean Ltd for a safety device that did not operate and Halliburton for not cementing the well properly.

After 87 days of leakage the oil leak was finally cut off on the 19th of September 2010. In the meantime, the Flow Rate Technical Group gave its own estimate of 20,000-40,000 bpd. It is obvious that the event is quite unique mainly because of all the announcements regarding the oil leak. Nearly all the estimates were refuted and it was too difficult, especially after the explosion, to evaluate the size of the accident. These announcements always create uncertainty which leads to investment postponement and lack of funding.

CHAPTER 5 Data

For the purpose of the analysis, we collected historic daily share prices for drilling companies with NAICS code 213111 that were trading on the New York Stock Exchange (NYSE) at the time of the event. The share prices were collected from the DataStream and the Compustat databases. Our first sample consisted of 42 firms. However, due to lack of data that was needed either for the estimation window or the event window, our final sample ended up containing 34 drilling companies. In addition, daily prices of the S&P 500 Oil and Gas Drilling sub-index were collected from the Datastream. The sub-index is used to proxy for the market portfolio in the calculation of the normal returns.

Company Name	***Exposure***	***Location***
ATWOOD OCEANICS	11.11%	GOM
BAKER HUGHES INC	16.86%	GOM
ENSCO PLC	17.65%	GOM
PARKER DRILLING CO	30.23%	GOM
ROWAN COMPANIES PLC	15.09%	GOM
NOBLE CORP PLC	12.90%	GOM
PRIDE INTERNATIONAL INC	33.33%	GOM
TRANSOCEAN LTD	10.87%	GOM
DIAMOND OFFSHRE DRILLING INC	31.91%	GOM
HERCULES OFFSHORE INC	58.62%	GOM
SEAHAWK DRILLING INC	100%	GOM

Table 2 Exposure Percentages

To designate whether a company is an “exposed” company, we cross-checked each company with their 10-k filings reported at the U.S. Securities and Exchange Commission (SEC). Drilling companies that had their rigs located at the Gulf of Mexico (GOM) prior to the event were characterized as “exposed” companies and the rest as “non-exposed”. The “exposure” variable was calculated as the number of the rigs located in the GOM for each company over the total number of the rigs that each company owns. Table 2 contains the exposure percentages of the first sample. Most of the companies in our sample had low exposure to the accident ranging from 10-30%, except for Hercules Offshore Inc. which had more than half of its fleet located in the GOM and Seahawk Inc which had all its operating rigs located in the GOM when the explosion occurred.

Variable Name	**Mean**	**Median**	**Maximum**	**Minimum**	**Std. Deviation**	**N**
Portfolio Returns						
“Exposed” Portfolio	-0.0453	0.0868	18.7038	-18.1224	2.858	11
Transocean	-0.0354	-0.0178	18.1235	-21.5979	2.9524	1
“Non-Exposed” Portfolio	-0.0230	-0.0125	6.7884	-5,7181	1.2553	23
“All” Portfolio	-0.0697	-0.0004	7.8688	-11.2058	1.9946	34
S&P 500 sub-index	0.3796	0.1875	19.3655	-20.7120	3.2539	1

Table 3 Descriptive Statistics

The companies that were collected where afterwards separated into two sub-samples. Our first sub-sample consists of 11 drilling companies that were listed on the New York Stock Exchange (NYSE) and they are the companies that are designated as the “exposed” drilling companies, because at the time of the accident they were active in the GOM. This sample, also, includes the drilling company Transocean, which was the owner of the rig that suffered the explosion on the 20^{th} of April 2010. In addition, Transocean is, also, examined separately, because it was one of the firms that were responsible for the accident and it was involved in the debate regarding the accountability of the incident. The second sample consists of the companies whose main activity is offshore drilling and at the time of the accident their rigs were not situated in the GOM. From these two samples we created the “exposed”, “non-exposed” and “all” value-weighted portfolios.

In table 3 we report the descriptive statistics for the 208 trading day period (196 before the event and 12 after the event) that is used in our analysis. The mean of the value-weighted returns of all our portfolios is lower than the median, which shows that our data are skewed to the left, whereas the mean of the S&P 500 Oil and Gas Drilling sub-index is greater than the median meaning that the market returns are skewed to the right. Furthermore, the values of the standard deviation of our “exposed” portfolio, Transocean Ltd and the sub-index are quite high meaning that the data is spread over a wide range of values, whereas the values of the standard deviation of the value-weighted returns of the “non-exposed” and “all” portfolios are lower meaning that the data is more concentrated around the mean value.

CHAPTER 6 Methodology

6.1 Event Study Methodology

In our study we examine and analyze the effect that the accident that took place at the GOM and all the events that followed the explosion had on the share prices of drilling companies by using event study methodology. According to previous studies the financial markets did not react rapidly to the accident. In fact, according to Fodor and Stowe (2010), and Friedman and Friedman (2010) it took about 9 days for the financial market to fully respond to the event. Thus, to examine all the cases we constructed two event windows, where the first event window includes a period of 4 trading days with the first day being the day of the accident. The 12-day event window was constructed to consist of 12 trading days after the explosion with the day of the explosion being the first day. In this case we extend the period following the previous studies and the late reaction.

We denote the day of the event (21th of April 2010) as t_0, where $t_0 = 0$, the first day of the event window as t_1 and the last day of the event window as t_2. Since the accident occurred in the night, we define as the first day of the event the 21st of April 2010, when the financial markets received the information. Thus, the two event windows are $(t_1, t_2) = (1,4)$ and $(t_1, t_2) = (1,12)$. The estimation window, that is used to estimate the normal returns, consists of 196 trading days prior to the event. The first day of the estimation window is denoted as t_3 and the last day of the estimation window as t_4, so that the estimation window is $(t_3, t_4) = (-225, -30)$. The length of both windows is calculated as $L_1 = (t_2 - t_1 + 1)$ for the event window and $L_2 = (t_4 - t_3 + 1)$. The daily returns of our portfolios were estimated using the single index market model. The single index market model over the estimation window of (-225, -30) was estimated using the following equation:

$$R_{i,t} = \alpha_i + \beta_i \cdot R_{m,t} + \varepsilon_{i,t}, \quad t = -225, \dots, -30$$

where,

$R_{i,t}$ = *The daily return of the ith observation on day t*

$R_{m,t}$ = *The daily return of the* S&P 500 Oil and Gas Drilling sub − index *on day t*

The estimated parameters α_i and β_i from the previous equation are used to calculate the abnormal return (AR) of portfolio i on day t as follows:

$$AR_{i,t} = R_{i,t} - \left(\alpha_i + \beta_i \cdot R_{m,t}\right)$$

The cumulative abnormal returns (CAR) over the two event windows are calculated by summing the abnormal returns (AR) for each portfolio, as follows:

$$CAR_i(t_1, t_2) = \sum_{t=t1}^{t2} AR_{it}$$

To determine whether the event had an effect on our portfolios, the cumulative abnormal returns should be different than zero ($CAR \neq 0$). This means that the null hypothesis $H_0\colon CAR_i = 0$ should be statistically rejected. The significance test for each portfolio is calculated as follows:

$$t_{CAR} = \frac{CAR_i}{S_{CAR_i}}$$

where,

S_{CAR_i} = *The standard deviation of the cumulative abnormal returns*

The variance of the cumulative abnormal returns is calculated as the length of the event window multiplied by the variance of abnormal returns, as follows:

$$S^2_{CAR} = L_2 \cdot S^2_{AR_i}$$

Thus, the standard deviation is obtained by the square root of the variance of the cumulative abnormal returns, as follows:

$$S_{CAR} = \sqrt{S^2_{CAR}}$$

To test whether our results are robust and to control for the event induced volatility which can caused too frequent rejections of the null hypothesis we the standardized cross-sectional test (Boehmer, Musumecu and Poulsen, 1991). The formula used to calculate the test is as follows:

$$BMP = \frac{\overline{CSAR}(t_1, t_2)}{S_{CSAR}}$$

where, $\overline{CSAR}(t_1, t_2)$ is the cross-sectional average of the cumulated standardized abnormal returns and S_{CSAR} the standard deviation of the standardized cross-sectional average of the cumulated standardized abnormal returns. To obtain the $\overline{CSAR}(t_1, t_2)$, we need first to calculate the cumulated standardized abnormal returns ($CSAR$) with the following formula:

$$CSAR(t_1, t_2) = \sum_{i=t_1}^{t_2} \frac{AR_{i,t}}{S_{AR_I}}$$

Then the cross-sectional average of the cumulated standardized abnormal returns $\overline{CSAR}(t_1, t_2)$ can be obtained by:

$$\overline{CSAR}(t_1, t_2) = \frac{1}{N} \sum_{i=1}^{N} CSAR_i(t_1, t_2)$$

Finally, we can compute the standard deviation of the standardized cross-sectional average of the cumulated standardized abnormal returns S_{CSAR} by using the following formula:

$$S_{\overline{CSAR}}^2 = \frac{1}{N((N-1)} \sum_{i=1}^{N} [CSAR_i(t_1, t_2) - \overline{CSAR}(t_1, t_2)]^2$$

6.2 Exposure Effect Methodology

In addition, to explore our third hypothesis "*The larger the exposure to the Gulf of Mexico oil spill is, the larger the stock price hit* ", we had to examine the value of the hit for the companies that were exposed to the event. To investigate the value of the hit we examined the returns of each company separately and estimated the cumulative abnormal returns with the event study methodology that was used for our portfolios and examined the relationship between the CARs and the percentage of exposure that each company had. If our hypothesis is right then the cumulative abnormal returns should be negative and statistically significant for the event window and the higher the exposure to the event the lower the CARs.

To examine the relationship of the CARs with the percentage of exposure for each company we use an Ordinary Least Squares (OLS) regression. The 4-days and 12-days cumulative abnormal returns ($CAR = [1,4], CAR = [1,12]$) of each company are the key dependent variables, the percentage of exposure of each company (*Exposure*) is the key independent variable and the oil price as a control variable. The formula of the OLS regression is as follows:

$$CAR_{i,t} = \alpha + \beta_1 \cdot Exposure_{i,t} + \beta_2 \cdot Oil\_Return_t + \varepsilon_i$$

where,

$Exposure_{i,t} = The\ percentage\ of\ exposure\ for\ the\ company\ i\ on\ t\ period$

$Oil\_Return_t = The\ oil\ return\ for\ the\ period\ t$

$\varepsilon_i = The\ robust\ standard\ error$

CHAPTER 7 Results

7.1 Stock Price Responses

To begin with, we analyze the Cumulative Abnormal Returns of our portfolios in order to confirm our hypotheses. Table 4 displays the CARs and the results of the t-Test that calculates the statistical significance of our results (as said, nowadays a battery of parametric and nonparametric tests are available). To accept a result as statistically significant the score of the t-test should be equal to or higher than 1.96 which is the z-critical value for a two tailed test of the 95% confidence interval. According to our results the only portfolio that had the expected results was the "exposed" portfolio for the event window of the 12 days after the explosion which is based on the late reaction of the financial markets. Thus, we are able confirm previous studies that indeed the financial markets responded slowly to the accident.

Regarding the 4 days event window the CARs of the U.S. drilling companies were positive and close to zero, which is also the case for the "non-exposed" companies, meaning that for this period the stock prices did not move abnormally. On the other hand the CAR of the "exposed" was negative, according to our expectations, however, none of the results are statistically significant and the null hypothesis was not rejected, which shows that the event did not impact the U.S. drilling companies these 4 days, regardless the levels of exposure.

	(1,4)		(1,12)	
PORTFOLIO	**Cumulative Abnormal Returns**	**t-Test**	**Cumulative Abnormal Returns**	**t-Test**
EXPOSED	-1.5887	-0.2646	-8.9196	-2.2589**
NON-EXPOSED	3.2779	0.4705	5.1587	1.2352
ALL	-1.0152	-0.5161	-7.7618	-1.9725**

Table 4 CARs and t-test is the t test based on robust standard errors?

*** p<0.01, ** p<0.05, * p<0.1

More specifically, the value-weighted CAR (1,4) of the portfolio of all the exposed drilling companies of our sample is -1.5887 and the null hypothesis cannot be rejected, as the score of the t-test is way lower than the critical value of 1.96. The non-exposed companies had positive statistically insignificant CAR (1,4) and the designated as "all" portfolio that consists of all the firms in our sample had negative statistically insignificant CAR (1,4). In general, the fact that the CAR of the portfolios are closer to zero and the fact that the results of the t-test were low indicate that the portfolios' performance for the 4 day period after the event is quite close to the benchmark's performance. Thus, we can argue that the financial markets did not respond to the event these 4 days, with our portfolios' returns being unaffected.

Regarding the 12 days event window $(t_1, t_2) = (1{,}12)$ our results show that, as expected, the "exposed" portfolio had negative CAR(1,12) in the designated period, which are statistically significant. More specifically, the CAR(1,12) of the exposed portfolio equals to -8.9196 being statistically significant within the 95% confidence interval. This illustrates that the drilling firms that were active in the GOM at the time of the accident suffered abnormal returns as a whole and their returns were directly affected by the event. Furthermore, the portfolio of the companies that had no activity at the GOM at the time of the accident showed negative CAR(1,12), which was estimated as 5.1587. However, the results that we obtained for the portfolio are again statistically insignificant meaning that we cannot reject the null hypothesis and that there was no effect from the event on these non-exposed companies. Finally, the "all" portfolio showed negative CAR(1,12) similarly with the 5-day event window that were estimated to be -7.7618. However, for the 12 days event window the CAR(1,12) are statistically significant within the 95% confidence level which indicated that the portfolio's returns similarly with the "exposed" portfolio were impacted by the event.

In table 5 we look at all the ARs and CARs of the "exposed" portfolio and Transocean Ltd, the owner of the rig that suffered the explosion, within the 12 days event period (+1,+12). We can see that the CAR of Transocean Ltd is consistently more negative than the CAR of the "exposed" portfolio. This can, also, be derived from figure 1 which demonstrates the movement of CARs across all the dates. The figure illustrates more clearly the fact that the financial markets were slow to react to the event. On the date that Fodor and Stowe (2010), and Friedman and Friedman (2010) found as the reaction date for the financial markets, Transocean Ltd had abnormal returns reaching up to -20.1659%. On the other hand, the "exposed" portfolio's CAR declines more smoothly, which can also be derived by the ARs, which do not show any aggressive movements. Furthermore, the positive ARs that occur at certain days could be due to the misleading announcements and the inability to assess the magnitude of the accident. The conflicting announcements between the researchers and the fact that BP was consistently trying to downgrade the size of the disaster were the main reason for investors to react slowly.

Day	***Exposed Portfolio***		***Transocean Ltd***	
	AR	*CAR*	*AR*	*CAR*
+1	*-1.7371*	*-1.7371*	*-1.7188*	*-1.7188*
+2	*0.2041*	*-1.533*	*-0.9244*	*-2.6432*
+3	*0.0201*	*-1.5129*	*-1.3782*	*-4.0214*
+4	*-0.0758*	*-1.5887*	*-1.4090*	*-5.4305*
+5	*-1.1371*	*-2.7258*	*0.9090*	*-4.5214*
+6	*-1.2395*	*-3.9653*	*-5.8629*	*-10.3844*
+7	*-2.5023*	*-6.4676*	*-6.4237*	*-16.8082*
+8	*-2.8367*	*-9.3043*	*1.9335*	*-14.8746*
+9	*0.7456*	*-8.5587*	*0.9700*	*-13.9046*
+10	*-0.3877*	*-8.9464*	*-0.3776*	*-14.2823*
+11	*0.0900*	*-8.8564*	*0.1787*	*-14.2644*
+12	*-0.0632*	*-8.9196*	*-5.9015*	*-20.1659*

Table 5 ARs and CARs of exposed companies and Transocean Ltd 12-days period.

1) *Estimation Window 196 trading days*
2) *Event period +1 to +12 trading days.*

To sum up the analysis of the CARs, regarding the first hypothesis (H_1), we were only able to confirm it for the 12-days event period, because according to our results the stock prices of all the U.S. drilling companies in our sample as a whole were not impacted by the event in the short-term event period. In that case the CARs were statistically insignificant which proves that there is no impact from the event in contrast to the long-term period where the results were statistically significant at the 95% confidence interval. In addition, the stock prices of the "exposed" portfolio were, also, affected by the event but again only for the 12 days event window (1,12). The CAR of the non-exposed portfolio was positive for both event windows contrary to our predictions and statistically insignificant. As a result the event had a more negative effect on the stock prices of the exposed U.S. drilling companies compared to the non-exposed for the 12 days event window. On the other hand, for the short-term event window (1,4) both portfolios' returns remained unaffected by the accident and no abnormality was observed. Thus, we are able to confirm our second (H_2) hypothesis that the event had an effect on the exposed U.S. drilling companies only <u>for the long-term period</u>.

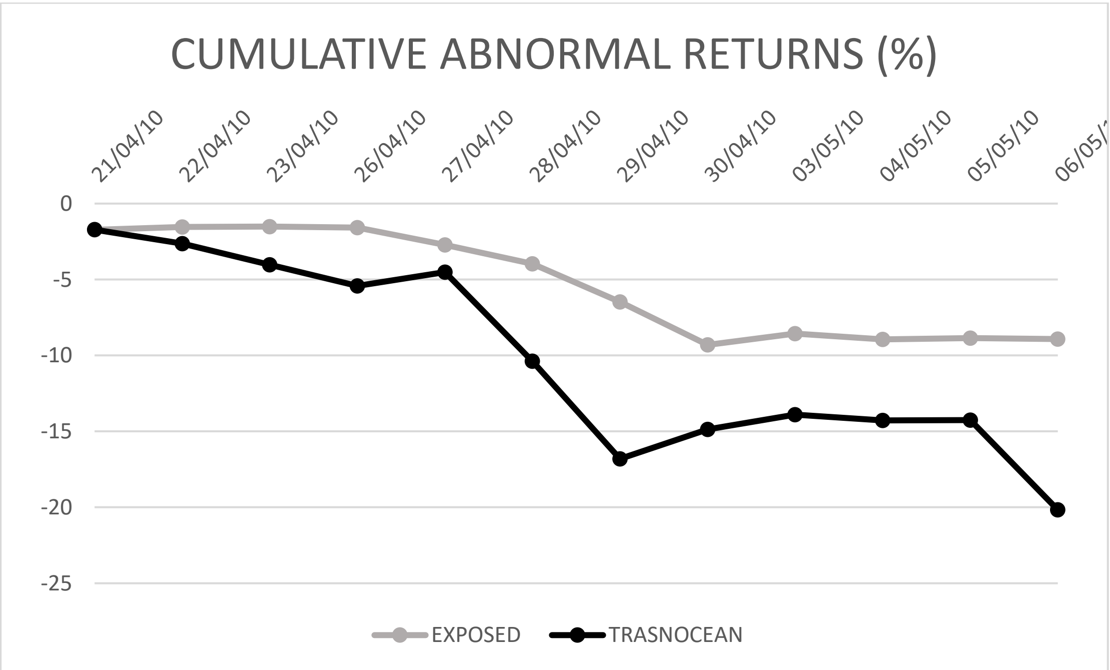

Figure 1 CARs movement of Exposed portfolio and Transocean Ltd

We were, also, able to confirm earlier studies that the reaction was not rapid and that for the first 5 days the event had no effect on none of our portfolios. Furthermore, when we constructed our event window around the reaction day that prior studies indicated, we were able to confirm our hypotheses regarding the exposed companies. Finally, when comparing the CARs of the "exposed" portfolio and Transocean Ltd over the event window we showed that Transocean Ltd had more negative CARs, which, also, declined more sharply over the event window, illustrating that the company received a significant hit mainly because it owned the Deepwater Horizon oil rig.

7.2 Exposure Effect

In the previous section we analyzed the market capitalization value weighted CARs of our portfolios and Transocean Ltd and we were able to determine the effect of the explosion in the GOM on the exposed U.S. drilling companies. In this section we aim to test our third hypothesis (H_3) and examine whether the exposure to the oil spill had a significant impact on the magnitude of the effect of the event on the U.S. drilling companies. After indicating the effect of the accident it is crucial to determine whether the more diversified companies, with rigs in different drilling areas were able to endure the hit on the stock prices from the event and whether less diversified companies which were more concentrated in the GOM area for their drilling activities suffered more negative abnormal returns. Thus, we aim to show that the concentration in the GOM and high levels of exposure affected the level of CARs for each company.

To test the impact of the exposure to the oil spill on the magnitude of the effect of the event window on the stock prices of the U.S. drilling companies we used all the firms in our sample, both the exposed and the non-exposed firms, and conducted an OLS regression analysis for each of the event windows. The dependent variable in our analysis is the CARs of the firms in our sample and the independent variable is the exposure to the risk, which is the percentage of a company's rigs that were located in the GOM over all the company's rigs. The oil price returns are used as a control variable as they are also related to the companies' CARs. We ran regressions for both the long term and the short term event window. First, we only incorporated the independent variable in our model and then we also added the oil price returns.

Table 6 displays the results of the regression analysis. From these results we are able to extract valuable information. First of all, as expected, for the 4 days event window (1,4) the exposure did not have any significant effect, as the null hypothesis could not be rejected even though the coefficient of the independent variable (exposure) is negative.

This was expected because our former analysis showed that the event had no effect on the stock prices of the U.S. drilling companies for this event window and thus the exposure could not have an effect as well. So, the results of the two analyses agree and we are not able to accept the third hypothesis (H_3) for the 4 days event window (1,4).

Event window	**(1,4)**	**(1,4)**	**(1,12)**	**(1,12)**
Variables	**Cumulative Abnormal Returns**	**Cumulative Abnormal Returns**	**Cumulative Abnormal Returns**	**Cumulative Abnormal Returns**
Exposure	-0.0529	-0.0551	-0.0810**	-0.0807**
	(0.0595)	(0.0593)	(0.0361)	(0.0363)
Oil Price Returns		0.0247		0.0058**
		(0.0163)		(0.0042)
Constant	0.0080	-0.0056	-0.0053	-0.0035**
	(0.0117)	(0.0134)	(0.0076)	(0.0081)
Observations	120	120	273	273
R-squared	0.336	0.267	0.373	0.446

Table 6 Regression Analysis Results on the Impact of Exposure

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Next, we conducted the same analysis for the 12 day event window (1,12). For this event window the stock prices of the exposed U.S. drilling companies were impacted by the event, while the accident had no effect on the stock prices of the companies that were not exposed. Thus, the investors were sensitive to the general exposure of the firms and it is important to determine even further whether the level of exposure was crucial for the magnitude of the effect on the stock prices. According to our results in table 6, the coefficient of the exposure which is the independent variable is negative, which indicates that an increase in the exposure would decrease the CAR of the U.S. drilling companies. Thus, a higher level of exposure to the event would result into a higher level of negative CAR. Furthermore, the results are statistically significant at 5% level of significance and the null hypothesis is rejected.

After incorporating the oil price returns in our model and running the OLS regression for both the short-term and the long-term period we can observe that the coefficients of the exposure to the event are close to the ones of our previous analyses and again only for the 12-days period the coefficient is statistically significant at a 95% confidence interval. Regarding, the oil price returns which is the control variable it can be observed that only in the long-term period the positive coefficient is statistically significant at a 5% level of significance. Again, the fact that for the short-term period our results are not statistically significant can be explained from the statistically insignificant CARs that we obtained in the earlier analysis on the CARs.

To sum up, after conducting the OLS regression analyses we showed that exposure did affect the reaction of the stock prices of the U.S. drilling companies only for the 12 days event window. For the 4 days event window, since there was no effect of the event on the stock prices the negative results regarding the effect of the exposure variable were expected. Thus, we can accept our third hypothesis (H_3) for the 12 days event window. From these results we can extract the conclusion that even if a company was exposed to the oil spill and its stock prices were affected by the event, being diversified and less concentrated in the GOM area would act as an inhibitor to the negative reaction of the investors. On the other hand, the stock prices of companies more concentrated in the GOM area declined more sharply in this long-term period as the investors were sensitive to the exposure.

7.3 Robustness Check

To confirm the results of our analyses we conduct a robustness check. For the purpose of the robustness check we run a different test, than the t-test that we used in our analysis, to obtain the significance of our results. The test we use is the standardized cross-sectional or BMP test, that also controls for the event induced volatility. The results that we obtained from the BMP test align with the results of the t-test of our analysis for the exposed and the all portfolio for the 12-days event window. These CAR(1,12) are statistically significant within the 95% confidence level. In addition, the CAR(1,4) for the exposed, the non-exposed and the all portfolio as well as the CAR(1,12) for the non-exposed portfolio are statistically insignificant similarly to what we obtained from the t-test of our analysis. As a result, we can confirm that our results are robust based on our analyses as could obtain the same results with both significance tests.

	(1,4)		(1,12)	
PORTFOLIO	**Cumulative Abnormal Returns**	**BMP-Test**	**Cumulative Abnormal Returns**	**BMP-Test**
EXPOSED	-1.5887	-0.2660	-8.9196	-2.3152**
NON-EXPOSED	3.2779	0.4697	5.1587	0.4267
ALL	-1.0152	-0.7168	-7.7618	-2.2448**

Table 7 CARs and BMP test

CHAPTER 8 Conclusion

8.1 Discussion

In this event study we examine the effect of the explosion and following oil spill at the Deepwater Horizon oil rig, which was located at the Gulf of Mexico and was owned by Transocean Ltd, on the stock prices of the U.S. drilling companies. From our analysis we were able to obtain valuable results, which we report. The research question of our analysis is : *how did the GOM oil spill in 2010 impact the share price of the U.S. drilling companies and what was the impact of the exposure on the magnitude of the effect on the companies' share prices?* In addition the three hypotheses that we tried to answer are:

H_1*: The 2010 oil spill in the Gulf of Mexico has had a significant negative impact on the share price of all the U.S. drilling companies.*

H_2*: The 2010 oil spill in the Gulf of Mexico has had a more significant negative impact on the share price of the exposed, compared to the non-exposed U.S. drilling companies.*

H_3*: The larger the exposure to the Gulf of Mexico oil spill is, the larger the stock price hit.*

First of all, we examined the effect of the event on the stock prices for two event windows, consisting of 4 and 12 days respectively. We were able to show that for the 4 days event window (1,4) the accident had no effect on the stock prices of both the exposed and the non-exposed U.S. drilling companies and there were no abnormal returns resulting from the event. The 12 days event window (1,12) was constructed to include 12 days after the explosion based on previous studies which proved that the financial markets reacted slowly to the accident (Fodor and Stowe 2010; Friedman and Friedman 2010). For this event window our findings indicate that the event had a statistically significant effect on the stock prices of the exposed U.S. drilling companies, whereas there was no effect on the non-exposed U.S. drilling companies. In addition, we were able to show that the industry of the drilling companies in the U.S. was impacted by the accident only for the long-term event window and thus we could accept our first hypothesis (H_1) for this period.

Based on these results we showed that the investors were sensitive to the exposure to the oil spill risk in a long term base because the non-exposed companies did not suffer any abnormal returns meaning that their stock prices were not affected in contrast with exposed companies. Thus, we were able to accept our second (H_2) hypothesis in the long-term event window. Furthermore, we can confirm the findings of previous studies that indicated that there was a delayed reaction to the event and that the markets reacted late to accident's recorded date. Finally, from the analysis of the CARs we showed that the magnitude of the effect on the stock prices of Transocean Ltd was higher than the effect on the "exposed" portfolio, indicating that the owner of the Deepwater Horizon rig suffered more negative abnormal returns.

To determine whether the level of exposure had a significant impact on the magnitude of the effect on the stock prices, we conducted an OLS regression analysis between the CARs of the U.S. drilling companies of our sample and the obtained level of exposure that was constructed from the annual statements of the companies in our sample. As expected, regarding the 4 days event window we had insignificant results, which is explained by the fact that the event had no effect on the stock prices of the U.S. drilling companies for this period. For the 12 days event window, we found that the investors were sensitive not only to the exposure to the oil spill risk but also to the level of the exposure. More specifically, more diversified companies were not impacted by the event as much as the more concentrated in the Gulf of Mexico. Thus, our third (H_3) hypothesis was accepted for the 12 days event window and we can argue that for the Deepwater Horizon accident the higher the exposure to the event the higher the hit to the stock prices of the U.S. drilling companies.

Overall, the results indicate that the investors did react to the accident but they reacted slowly due to the existing difficulties in the assessment of the size of the disaster and they were more sensitive to the level of exposure and the concentration of a company's rigs in the Gulf of Mexico.

8.2 Limitations and Recommendations

On this section certain limitations and recommendations for future research should be noted regarding our study. Due to the way our sample was constructed, where we focused to companies with a certain NAICS code that were trading on the New York Stock Exchange (NYSE) at the time of the event, we ended up with a small-sized portfolio of companies that were exposed to the event with some of them being relatively big and some quite smaller. As a result it would add value to construct a larger sample which could be more representative. In addition, since stocks sometimes over- and underreact a comparison with accounting measures such as return on assets (ROA), return on equity (ROE), earnings and sales would be a valuable addition to our research.

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Appendix

Company Name	NAICS	SIC	Ticker Symbol
ATWOOD OCEANICS	213111	*1381*	*ATW*
BAKER HUGHES INC	213111	*1381*	*BHGE*
ENSCO PLC	213111	*1381*	*ESV*
PARKER DRILLING CO	213111	*1381*	*PKD*
ROWAN COMPANIES PLC	213111	*1381*	*RDC*
NOBLE CORP PLC	213111	*1381*	*NE*
PRIDE INTERNATIONAL INC	213111	*1381*	*PDE*
TRANSOCEAN LTD	213111	*1381*	*RIG*
DIAMOND OFFSHRE DRILLING INC	213111	*1381*	*DO*
HERCULES OFFSHORE INC	213111	*1381*	*HERO*
SEAHAWK DRILLING INC	213111	*1381*	*HAWK*

Table 7 NAICS SIC code and Ticker symbol of Exposed companies.

Company Name	NAICS	SIC	Ticker Symbol
ALLIS-CHALMERS ENERGY INC	213111	*1381*	*ALY*
NABORS INDUSTRIES LTD	213111	*1381*	*NBR*
WEATHERFORD INTL PLC	213111	*1381*	*WFTIF*
KEY ENERGY SERVICES INC	213111	*1381*	*KEG*
CALFRAC WELL SERVICES LTD	213111	*1381*	*CFW*
CATHEDRAL ENERGY SVCS LTD	213111	*1381*	*CET*
PRECISION DRILLING CORP	213111	*1381*	*PD*
AKITA DRILLING LTD	213111	*1381*	*AKTAF*
ENSIGN ENERGY SERVICES INC	213111	*1381*	*ESI*
PATTERSON-UTI ENERGY INC	213111	*1381*	*PTEN*
OMNI ENERGY SERVICES CORP	213111	*1381*	*OMNI*
WESTERN ENERGY SERVICES CORP	213111	*1381*	*WRG*
TECHNICOIL CORP	213111	*1381*	*TEC*
PHX ENERGY SERVICES CORP	213111	*1381*	*PHX*
SAVANNA ENERGY SVCS CORP	213111	*1381*	*SVY*
IROC ENERGY SERVICES CORP	213111	*1381*	*ISC*
TRINIDAD DRILLING LTD	213111	*1381*	*TDG*
UNION DRILLING INC	213111	*1381*	*UDRL*
STONEHAM DRILLING TRUST	213111	*1381*	*SDG.UN*
BRONCO DRILLING CO	213111	*1381*	*BRNC*
PANTERA DRILLING INCOME TR	213111	*1381*	*RIG.UN*
CALMENA ENERGY SERVICES INC	213111	*1381*	*CEZ*
XTREME DRILLING CORP	213111	*1381*	*XDC*

Table 8 NAICS SIC code and Ticker symbol of Non-Exposed companies.