Major Hurricanes in the Gulf of Mexico: The Pre-Announcement Stock Market Response

by

Kirk Philipich
Assistant Professor of Accounting
University of Michigan – Dearborn

Young Ro
Assistant Professor of Operations Management
University of Michigan – Dearborn

Vivek Sharma
Assistant Professor of Finance
University of Michigan – Dearborn

ABSTRACT

Past research has shown that firm announcements regarding their supply chains are not overlooked by the stock market. The stock market reacts positively to enhancements or negatively to disruptions in firm supply chains. Some have conjectured that the observed market reactions to announced enhancements or disruptions understate the importance of the firm's supply chain to the market value of the firm. We show that the market revalues firms once an impending Gulf Coast major hurricane presents a real danger of potentially disrupting the oil and gas supply chain. Major hurricanes posing a greater threat to the oil and gas supply chain lead to larger negative market reactions than those hurricanes that pose little if any threat. We also show that the market's reaction is related to not only the eventual location of the major hurricane's landfall, which proxies for the threat to the oil and gas supply chain, but also to the variability of oil prices during the period of time the major hurricane strikes. Our results lend even more credence to the importance of the supply chain to the stock market by identifying a setting in which the market reacts before the firm announces a potential or actual supply chain disruption.

1. Introduction

The primary goal of this research is to provide additional empirical evidence on the importance of the firm's supply chain to the firm's stakeholders. Obviously, the entire supply chain, beginning with the acquisition of raw material and labor and ending with the sale and delivery of final products, is the value creation process through which all stakeholders are enriched. Our focus in this research is on the equity investor and how potential disruptions to the supply chain or disruptions that are in progress, yet go unannounced by firm management, may negatively impact equity investors.

Prior research shows that announcements of supply chain disruptions negatively impact firm performance (Hendricks and Singhal 2005a), negatively impact stock prices at the time of the disruption is announced (Hendricks and Singhal 2003), and may signal long-term underperforming stocks as well (Hendricks and Singhal 2005b). Certainly, once a firm announces difficulties with its value creation process the market will immediately estimate the negative impact this has on the firm's ability to generate future cash flows and negatively impact stock prices. Our focus is not on firm announced disruptions to the supply chain but rather to determine if the stock market, through other means, is aware of possible supply disruptions even before firm announcements of supply chain disruptions are forthcoming. We show that the stock market is even more concerned with disruptions to the supply chain than previous research has been able to document by showing the market reacts to yet to be announced potential or currently occurring disruptions to the supply chain.

Specifically, we examine the stock market's reaction to major hurricanes on oil and gas firms with operations in the Gulf Coast region. The delivery of oil and gas is certainly critical to the entire U.S. economy and so it is not surprising that oil and gas firms are closely monitored by financial analysts and the existence of major hurricanes in the Gulf region is also well publicized and thus, well-known by stock market participants. Thus, market participants may impound into stock prices the likelihood that major hurricanes will impact the supply chain of oil and gas firms before these firms experience actual damage that cause disruptions to their supply chain, much less before announcements of disruptions are made by these firms.

We select a sample of oil and gas firms with operations (drilling platforms, terminals, pipelines, and/or onshore refineries) in the Gulf Coast region and use the twenty-one major hurricanes occurring between 1961 and 2005 that came ashore on the entire Gulf Coast, Brownsville, Texas to the Gulf Coast of Florida, as our events of interest. We use the eventual landfall location as a proxy for the possible or perceived threat to, or disruption in, the supply chain. Using the day each hurricane came ashore as day (0) in an event study, we find significant negative abnormal returns for one day prior to landfall, day (-1), and for the accumulated abnormal returns for the day prior to and the day of landfall, days (-1, 0) for those hurricanes that posed a threat to the oil and gas supply chain. The results seem to indicate that the stock market reacts to the threat posed by these hurricanes even though the firms have remained silent. The observed reaction occurs before firms announce disruptions to their supply chain and the day (-1) reaction could also indicate that the market anticipates supply chain disruptions that may or may not actually occur. Finally, we show that not only are the timing of the hurricane, the day of the week that the hurricanes reaches land, and its landfall location important variables to the stock market's reaction, and following past research regarding the impact of the volatility of oil prices on stock prices, we show that oil price volatility at the time of the hurricane also significantly impacts the stock market's reaction.

The next section discusses major hurricanes and attempts to develop an *a priori* prediction of the timing and direction of the stock market's reaction to these storms. Section 3 describes our sampling procedures. Section 4 develops the event study methodology employed and presents the empirical results. The final section summarizes the paper.

2. Hurricane Events and the Timing of the Market's Reaction

Hurricanes are classified according to the Saffir-Simpson Hurricane Scale which uses a 1-5 rating (1 being the least intense and 5 being the most intense hurricanes) based on the hurricane's present intensity (http://www.nhc.noaa.gov/aboutsshs.shtml). Wind speed is the primary factor that differentiates the expected damage from different category hurricanes. Hurricanes rated as category 3 and higher are considered to be major hurricanes by the National Hurricane Center (NHC) because of the extensive and usually widespread damage inflicted by these hurricanes. The stock market's awareness of and reaction to the potential impact of major hurricanes on the oil and gas supply chain is the subject of our study.

A hurricane's category can change substantially in a matter of hours because hurricane wind speeds are constantly changing. For example, in 2005 Hurricane Katrina was a category 5 hurricane over the central Gulf of Mexico. However, in less than two days it had weakened to a category 3 by the time it reached land near New Orleans (Knabb et al. 2006). In order to objectively select a sample of major hurricanes we selected only those Gulf Coast hurricanes that were rated as category 3 or higher at landfall since 1961 when daily CRSP data becomes available.

A chronological list of all major hurricanes to come ashore between the west coast of the Florida peninsula and Brownsville, Texas since 1961 can be found on Table 1.[1] As Table 1 shows, only one of these twenty-one major hurricanes, Camille, came ashore on the Gulf Coast as a category 5 hurricane. Three came ashore as category 4 hurricanes, Carla, Charley, and Ivan. The remaining eighteen major hurricanes came ashore as category 3 hurricanes.

Table 1 details and Figure 1 shows the approximate landfall for these twenty-one hurricanes. Sixteen of these major hurricanes came ashore within the Corpus Christi to Apalachicola corridor (hereby referred to as the oil and gas corridor). It is this corridor which contains a preponderance of both onshore and offshore Gulf Coast oil and gas supply chain facilities.[2] The remaining five of these major hurricanes came ashore either south of Corpus Christi or on the west coast of the Florida peninsula where far fewer, if any, oil and gas supply chain facilities exist.

In order to form an *a priori* prediction of when the stock market may react to an impending oil and gas supply chain disruption due to a major hurricane threat, we examined the historical record of the NHC's historical error rates for predictions of tropical cyclone intensity and tracks.[3] In terms of predicting storm intensity, the official NHC forecast error rate changed very little over the 1990 to 2005 time period (Franklin 2006), with 2005 being the last year in which a category 3 hurricane or higher came ashore on the Gulf Coast. The approximate sixteen-year average of yearly error rates over this time period for 24, 48, and 72 hours before landfall forecasts of storm intensity at landfall were, respectively, 10, 16, and 19 knots. Since the average range of wind speeds for category 1-4 hurricanes is approximately 18 knots, the NHC forecasts of the severity of the impending storm was usually within plus or minus one category 72 hours before landfall. Thus, it seems the NHC provided a reasonably accurate forecast of the type of tropical cyclone to be expecting as early as 72 hours before landfall.

Forecasting the storm track appears to be more difficult.[4] As of 2005, the 2004 storm track predictions yielded the smallest yearly errors in NHC forecasts of the storm track for 24, 48, and 72 hours before landfall (Franklin 2006). For 2004, the approximate average 24, 48, and 72 hours before landfall errors were respectively, 60, 100, and 160 nautical miles. To put these error rates in perspective, the average error in these best ever NHC 72 hour ahead forecasts is approximately 33% of the distance between Corpus Christi and Apalachicola, our oil and gas corridor. Likewise, the average error in the best ever 48 hour before landfall storm track forecasts is approximately 25% of the distance between Corpus Christi and Apalachicola. Thus, a storm thought to be coming ashore at Galveston 48 hours

---

[1] The primary source of information concerning the hurricanes in our study (i.e. landfalls and category at landfall) is the National Hurricane Center's archive for hurricane seasons and can be found at http://www.nhc.noaa.gov/pastall.shtml.

[2] See http://www.gomr.mms.gov/homepg/lsesale/visual1.pdf for details of the Gulf coast oil and gas lease areas and the location of both onshore and offshore oil and gas facilities.

[3] Tropical cyclones include not only hurricanes, categories 1-5, but also tropical storms and tropical depressions. In all, there are seven types of tropical cyclones.

[4] The NHC forecasts the expected track of a storm by connecting forecasts of the storm's position at 12 hour increments.

before landfall, could, in fact, eventually not endanger Galveston at all. This is exactly what occurred with Hurricane Rita in 2005. Evacuation of Galveston began 48 hours before landfall, deaths ensued during the evacuation, and Hurricane Rita never endangered Galveston as it came ashore far to the north and east of Galveston (Gall and Parsons 2006).

Regnier (2008) provides additional evidence of the short lead times in accurate predictions of hurricane storm tracks and eventual landfalls. She reports that for all hurricanes striking both Galveston and New Orleans from 1950-2005, there was less than 48 hour notice of these strikes 77% of the time. Thus, precise storm track and landfall locations are not available until the storm danger is quite imminent in a vast majority of cases. Primarily due to the difficulty in predicting the exact track of a tropical cyclone, and to a lesser extent the possible error in forecasting storm intensity, we anticipate any market reaction due to an impending threat to the oil and gas supply chain should be observed very close to the date of landfall, day (0), perhaps no sooner than 24 hours before landfall, day (-1).

3. Oil and Gas Firm Sample Selection

In selecting a sample of oil and gas firms, the overriding concern is that all sample firms have some supply chain presence in the Gulf Coast region. The number of events, twenty-one, severely limits our ability to rely on randomization to filter out noise which could be introduced by selecting oil and gas firms without a supply chain presence in the Gulf Coast region because a Gulf Coast hurricane would not threaten their supply chain. Additionally, previous research on inter-firm information transfers might suggest that in some situations firms without Gulf Coast supply chain facilities could, in fact, benefit from a threat to their competitors' Gulf Coast supply chain (Lang and Stulz 1992 and Laux et al. 1998).

To eliminate, or at least reduce these possibilities, all sample firms are investigated to ensure they have in place drilling platforms, pipelines, terminals, and/or onshore refineries in the Gulf Coast region. Ensuring this Gulf Coast presence involves careful scrutiny of firm annual reports, firm histories gathered from firm websites, and other historical documentation. Some mention of Gulf Coast facilities have to be identified in order for the oil and gas firm to be included in our sample. If any doubt exists as to whether the firm had Gulf Coast facilities, then the firm is excluded from the sample. We attempt to insure that facilities are present in the Gulf Coast region for all hurricanes because our time period extends over forty years. If, however, it is impossible to verify that facilities were present in the Gulf Coast region for any of our sample firms for any of the hurricanes we examine, then this could potentially weaken our results.

The initial sample is comprised of all oil and gas firms identified by the NYSE as being "integrated oil and gas firms." We chose this initial sample believing that this classification gives the greatest chance of identifying oil and gas firms with some supply chain presence in the Gulf Coast region. Next, the initial sample is expanded using firms with an SIC industry classification of "petroleum refining," as reported by CRSP. A substantial intersection of firms exists between these groups, NYSE defined "integrated oil and gas firms" and CRSP defined "petroleum refining firms," primarily due to the fact that many of the firms defined by CRSP as "petroleum refining" were later merged into the firms defined by the NYSE as being "integrated oil and gas firms."

Each firm in this initial sample is checked, as previously discussed, to insure that all remaining sample firms have verifiable oil and gas supply chain facilities in the Gulf Coast region.[5] The number of firms in the portfolio for each major hurricane is reported on Table 1; the number of firms in each portfolio decreases over time. This decrease is primarily driven by merger activity within the oil and gas industry.

As an indication of how closely monitored the oil and gas firms in our sample are by the market, we calculate average number of analysts' earnings forecasts reported by IBES for each month that a major hurricane occurred since 1976, the year in which IBES analyst data becomes available. We found on

[5] Examples of firms that were eliminated during sample selection include China Petroleum & Chemical Corporation, Petro-Canada, and Ecopetrol S.A. from the NYSE listing of integrated oil and gas firms and Quaker State Corporation (known for refining Pennsylvania crude oil) from the CRSP petroleum refining industry classification.

average, 20.5 analysts' earnings forecasts for each firm in our sample. For all firms covered by IBES, the firm average is 6.3. Thus, on average our sample firms have more than three times the number of analysts producing earnings forecasts than for the average firm covered by IBES, indicating a significant level of interest in the oil and gas firms appearing in our sample.

Since our primary interest is in determining if the market reacts to a perceived or possibly impending oil and gas supply chain disruption prior to a firm announcement of any supply disruption, we examined *The Wall Street Journal Index* for firm announcements prior to the landfall date of each hurricane in order to ensure that all firms in the sample for each hurricane made no announcements related to the impending hurricane prior to landfall. We found no firm announcements regarding the hurricanes prior to these landfall dates. This leads us to believe that any market reaction identified before these major hurricanes reached land, our day (0), is due to: (1) the close monitoring by the market that these firms are subject to, and (2) common knowledge of the existence of a possible major hurricane threat to these firms' supply chains.

4. Methodology and Results

We gather daily returns from CRSP for our portfolio of oil and gas firms for each hurricane event. For each portfolio both market model abnormal returns and market adjusted abnormal returns are calculated. In order to estimate β for each firm i, we use 255 daily returns, all of which are before the holding period in order to maintain independence between the estimation period for β and the holding period. β_i is estimated using a value-weighted measure of the market return (r_{mt}) and each firm i's daily return is as follows:

$$r_{it} = \alpha + \beta_i(r_{mt}) + \varepsilon_{it} \tag{1}$$

Firm i's daily market model abnormal return (MAR_{it}) for day t is defined as the difference between its actual return for day t (r_{it}) and the β-weighted return on the value-weighted market portfolio for that day (r_{mt}) and can be expressed as:

$$MAR_{it} = r_{it} - \beta_i(r_{mt}) \tag{2}$$

The individual firm MAR_{it}'s are then averaged across all firms in the portfolio yielding portfolio-level market model abnormal returns. Firm i's daily market adjusted abnormal returns (AAR_{it}) are calculated by assuming all βs equal one. Thus, equation (2) becomes:

$$AAR_{it} = r_{it} - r_{mt} \tag{3}$$

To create portfolio-level market adjusted abnormal returns, the individual firm AAR_{it}'s are averaged as before.

The portfolio average β for each hurricane is shown on Table 1. These average βs range from a low of 0.47 for Hurricane Bret to a high of 1.59 for Hurricane Allen. We expect the oil and gas firms in our sample to be, on average, less risky than the market as a whole, as characterized by the fact that we find average β estimates for thirteen of our portfolios to be less than one. However, there are eight portfolio average βs above one. Even after excluding the largest observed average β (because it appears to be an obvious outlier) the range is still quite large, 0.68 (1.15 – 0.47). This range of βs could indicate that controlling for systematic risk may be important if we are to identify significant abnormal returns.

It is certainly possible that the stock market is more aware of and/or interested in hurricanes with expected storm tracks that have the potential to be more disruptive to the oil and gas supply chain. Because the availability of expected storm track information over such an extended period, 1961-2005, is unknown, we choose to proxy for this with the actual landfall location of each hurricane. We examine two landfall possibilities because those hurricanes reaching land where more oil and gas supply chain facilities exist may be more disruptive to the supply chain and thus, the market's reaction could easily vary depending upon the landfall location. The two landfall possibilities used in the analysis are: (1) the Corpus Christi to Apalachicola corridor (the oil and gas corridor), and (2) the two areas outside the oil and gas corridor, south of Corpus Christi and along the west coast of the Florida peninsula or south of Apalachicola (referred to as outside the corridor). Figure 1 provides a map illustrating the location of the preponderance of the U.S. Gulf Coast oil and gas facilities as well as the landfall location for the twenty-one major hurricanes.

4.1. Significance of Abnormal Returns

Table 2 reports both the mean percentage market model abnormal returns and the mean percentage market adjusted abnormal returns for three days prior to landfall through three days after landfall as well as various accumulation windows around the day of landfall. Because of the small number of hurricane events, we use Wilcoxon sign rank tests (median tests) to test the abnormal returns reported in Table 2 for significance. We choose the day of landfall as day (0) because it represents the only common point for all of the hurricanes. Several of the hurricanes began as storms and tropical storms in the Gulf, some very close to or in the oil and gas corridor. Other hurricanes began as storms off the coast of Africa, entered the Caribbean as hurricanes and eventually entered the Gulf coming ashore on the U.S. Gulf Coast. Some of these hurricanes “stalled” in the Gulf, gained strength, and then came ashore. Because of differences in how each hurricane originated and differences in each hurricanes behavior once in the Gulf, the number of days each hurricane is present in the Gulf varies significantly (see Table 1). Thus, the only reliable common point to use as day (0) would seem to be the date of landfall.

Panel A of Table 2 reports the abnormal returns for all twenty-one hurricanes. None of the individual days’ abnormal returns show any significance nor do any of the abnormal returns for any of the accumulation windows. This finding could be due to several factors that could be confounding the reported abnormal returns. First and foremost, perhaps the market never foresaw a threat to the oil and gas production facilities for those hurricanes with landfalls outside the oil and gas corridor because these hurricanes never approached the primary oil and gas production region. Secondly, perhaps there are other sources of “noise” that make the detection of significant abnormal returns difficult.

4.1.1. Potential Effects of Confounding Factors. During our examination of *The Wall Street Journal Index* for firm announcements prior to each hurricane’s landfall, we discover that immediately prior to landfall for two of the major hurricanes with landfalls within the oil and gas corridor (Hurricanes Alicia and Opal) stories appeared in *The Wall Street Journal* pertaining to the oil and gas industry as a whole. On October 3, 1995, the day before Hurricane Opal’s landfall, a story appeared in the Wall Street Journal entitled, “Oil Companies are Expected to Post Gains --- Quarterly Operating Profits Rise 20%, Analysts Say, Despite Chemical Woes” (Goldsmith 1995). This story reported that analysts were expecting increased quarterly earnings for four of our twenty-one sample firms. The story also reported that an additional five of our sample firms were expected to have increases in their profits over the prior year. For the day of the story, the day before Opal’s landfall we observe a market adjusted return abnormal return of 1.44% and a market model abnormal return of 1.18%.

On August 15, 1983, the day Hurricane Alicia entered the Gulf, a story appeared in *The Wall Street Journal* entitled, “Analysts See Rise in Earnings for Oil Industry, But Split Over Which Sectors to Recommend” (Winans 1983). The story stated, “Analysts who liked the oil stocks last winter and spring still believe that oil prices will remain stable and that the industry should begin showing healthier profits this quarter as general economic activity picks up.” Also, the story reported one analyst recommending two of our twenty-one sample firms. With respect to oil stocks, this analyst also stated, “We see some sells in the major domestics if stock prices strengthen, as we expect, in the coming weeks and months.” We observe a two-day market adjusted abnormal return of 3.19% and a two-day market model abnormal return of 3.56%.

Obviously, these reports forecasting substantial increases in profits throughout the entire industry, and the corresponding market reaction, may preempt any impact due to the impending hurricane. In an effort to reduce the noise in our abnormal returns due to these two stories, we initially eliminate these two hurricanes because of these major confounding effects. Therefore, this limits our usable sample of hurricanes coming ashore within the oil and gas corridor to fourteen for our Wilcoxon tests.

Another potential source of noise in our abnormal returns is the day of the week that the hurricane reached land. If, for example, the hurricane had a Monday landfall, then the actual day (-1) is Sunday. However, in the results reported in Panel A of Table 2, we include the previous Friday's returns as those for day (-1) even though this is actually three days prior to landfall. This could confound otherwise even more negative and significant day (-1) abnormal returns.

For example, Hurricane Celia had a Monday landfall (August 3, 1970) but it was still a tropical storm on the Friday before coming ashore.[6] Hurricane Celia did not reach even minimal hurricane strength until Saturday, August 1, 2005. Thus, by the close of markets on Friday there may have been little concern that this tropical storm could intensify and become a major hurricane that could impact the oil and gas supply chain. Similarly, Hurricane Katrina reached land on Monday, August 29, 2005, but had just entered the Gulf of Mexico on Friday, August 26, and was still hundreds of miles from its eventual landfall (Gall and Parsons 2006). Weather models as of Friday, August 26, were predicting landfall anywhere from Galveston to the entire west coast of Florida! It was only after markets had closed on Friday, August 26, that it became apparent to forecasters that Katrina would come ashore near New Orleans. It is possible that for these hurricanes with Monday landfalls the returns on Monday may be capturing all of the expected impact on the oil and gas supply chain. Thus, the days (-1, 0) accumulated market model returns may be less affected by Monday landfalls, but inclusion of these hurricanes could easily dampen the day (-1) results.

Hurricane events with Sunday or Labor Day landfalls may pose an even more severe problem. The returns on the preceding Friday are not a "pure" day (-1) effect and Monday's returns, Tuesday's in the case of a Labor Day landfall, do not necessarily capture a "pure" day (0) effect. It is quite possible that the hurricane came ashore on Sunday morning and by Monday reports of insignificant damage due to the hurricane are available and so lengthening the window may not be as helpful as it could be for hurricanes with Monday landfalls. It is possible that if day (-1) captures the market's reaction, then lengthening the window to include day (0) could capture more noise, especially for those hurricanes for which day (-1) is able to capture a "pure" day (-1) effect, hurricanes with landfalls on Tuesday through Saturday.

As shown in Table 1, five of the twenty-one major hurricanes had Sunday or Labor Day landfalls (Camille, Carmen, Elena, Dennis, and Allen) and five others came ashore on Monday (Carla, Celia, Katrina, Wilma, and Bret). Since these ten hurricanes together with the aforementioned Alicia and Opal constitute greater than one-half of our twenty-one hurricane sample, we attempt to control for the impact these potentially noisy events may have on our results.

4.1.2. Oil and Gas Corridor Results. In an attempt to control for the noise that could be present in the abnormal returns for the sixteen hurricanes that came ashore within the oil and gas corridor we exclude both Hurricanes Alicia and Opal as well as those hurricanes with landfalls that may present the greatest noise, Sunday and Labor Day landfalls. This leaves ten hurricanes with landfalls on Monday (excluding Labor Day) through Saturday. Panel B of Table 2 reports a mean day (-1) market model abnormal return of -0.52% (p=1%) and a days (-1, 0) market model abnormal return of -0.60% (p=1%). The market adjusted abnormal returns are similar with a mean day (-1) abnormal return of -0.47% and a mean days (-1, 0) abnormal return of -0.52% (p=5%). No other individual day proved to be significantly different from zero nor did the expanded accumulation windows.

Observing that day (-1) appeared to be the day on which the market reacted to these hurricanes led us to also eliminate the remaining hurricanes with Monday landfalls since their day (-1) returns are actually the returns for three days before landfall. Panel C of Table 2 reports the results for the remaining seven hurricanes with landfalls on Tuesdays through Saturdays. We find more negative mean returns than those

---

6 See http://www.nhc.noaa.gov/archive/storm_wallets/atlantic/atl1970-prelim/.

reported in Panel B of Table 2. The mean market model abnormal return for both day (-1) and days (-1, 0) is -0.63% (p=5%). The mean market adjusted abnormal returns are -0.47% for day (-1) and -0.58% (p=5%) for days (-1, 0). The fact that the largest negative returns and the only significant reaction appear one day prior to landfall could be due to the great difficulty in predicting a hurricane's landfall and leads us to believe that this reaction is solely due to the impending hurricane. The abnormal returns for the remaining four hurricanes (excluding one with a Sunday landfall) that came ashore outside the oil and gas corridor are insignificant (results not tabulated).

It seems the stock market reacts to unannounced (by specific firms) impending supply chain disruptions. The market is aware of the potential disruption to the oil and gas supply chain brought on by major hurricanes and attempts to adjust prices. The market does not appear to wait for firm specific reports of hurricane damage to or disruption in the supply chain to be forthcoming from these affected firms, as in Hendricks and Singhal (2003). Rather, the market is forming its own prediction of the damage to the value creation process these firms may suffer and the Hendricks and Singhal (2003) conjecture that their results may understate the market's reaction seems to be valid. Furthermore, these results indicate that the market is not reacting to this potential threat until there is a reliable forecast that the threat even exists.

4.2. Regression Results

In the previous section we attempted to control for observed factors that might impact the abnormal returns we observe for Gulf Coast hurricane events. Due to our limited sample size, a maximum of twenty-one hurricanes, we use nonparametric Wilcoxon tests. However, the use of nonparametric tests limits our ability to control for multiple factors simultaneously. Thus, in order to control for one factor (e.g. industry earnings news) while examining another factor (e.g. within or outside the oil and gas corridor) we are forced to eliminate the observations exhibiting the industry earnings news even though this could have reduced the power of subsequent tests and lead us to believe that other factors were not significantly impacting the abnormal returns.

To better capture the simultaneous effects of multiple factors, we use the following regression:

$$AR = \alpha + \beta_1 D_{WSJ} + \beta_2 OPV + \beta_3 (D_C)(OPV) + \beta_4 (D_{Day})(D_C)(OPV) + \varepsilon \qquad (4)$$

AR is the portfolio abnormal return for each hurricane for various windows. D_{WSJ} is a dummy variable equaling one for hurricanes Alicia and Opal that should capture a positive market response ($\beta_1 > 0$) to the positive earnings news (forecasts) concerning oil and gas industry profits reported in *The Wall Street Journal* at the time of these hurricanes.

OPV represents the volatility of crude oil prices. Many previous researchers find that either oil prices or its volatility affect both macroeconomic variables (Ferderer 1996 and Lee et al. 1995) and stock prices (Jones and Kaul 1996, Papapetrou 2001, and Aloui and Jammazi 2009). In fact, Sadorsky (1999) and Park and Ratti (2008) find that for the post-1986 time period, oil price volatility shocks explain a larger portion of real stock returns than do interest rates in several countries, including the U.S. Finally, Cong et al (2008) find that oil price shocks significantly impact some Chinese oil company returns. Thus, it is possible that OPV represents a "risk factor" that our abnormal return measures have ignored.

If OPV is viewed as a potential risk factor, then periods in which volatility (risk) is high should see lower (higher) returns to potentially bad news (good news) than in those periods in which volatility is relatively low. If, as we expect, the stock market perceived hurricanes that eventually came ashore within the oil and gas corridor as posing a greater threat to the oil and gas companies with facilities in the Gulf than hurricanes that came ashore before reaching the oil and gas corridor, then we should observe more negative returns for those hurricanes. If, OPV is a missing risk factor, then all returns, even those when no threat is present, should vary as OPV varies. Thus, the coefficient on OPV should be positive ($\beta_2 > 0$). However, when a negative threat to the oil and gas region becomes possible, then we expect that higher

OPV should lead to lower returns. Thus we include D_C, a dummy variable equaling one when the hurricane (16 hurricanes including Alicia and Opal) came ashore within the oil and gas corridor, Corpus Christi to Apalachicola, which when multiplied by OPV should result in ($\beta_3<0$).

Oil prices during the 1960's, particularly the early to mid 1960's, were relatively flat. Previous studies for which variability of oil prices during the 1960's is required use the Producers Price Index for oil as opposed to spot prices (Chen et al 1986, Jones and Kaul 1996, and Regnier 2007). As we discover, reported spot prices during the 1960's show no variability for years at a time. The Producers Price Index for oil, while also exhibiting little variation, has more variation than reported spot prices. We estimate OPV as the standard deviation in the monthly Producers Price Index for oil prior to each hurricane. We find that the fewest number of months yielding a non-zero standard deviation for all of our hurricanes during the 1960's is 30 months. Thus, to maintain consistency, we use the 30 months prior to the month in which each hurricane occurred to measure the OPV with the standard deviation in the Producers Price Index for oil. Since Regnier (2007) shows that the movement in the Producers Price for oil and the movement in oil spot prices are nearly identical, we believe that this is a good proxy for the volatility of oil prices.

Finally, based upon the Table 2 result that the returns for hurricanes with landfalls occurring on Tuesday through Saturday within the oil and gas corridor are slightly more negative than the returns for those hurricanes coming ashore on Sunday and Monday within the oil and gas corridor we include one final variable. D_{Day} is a dummy variable that takes the value of one when the hurricane's landfall occurs on Tuesday through Saturday. This observation along with our previous discussion of OPV, that perhaps OPV represents a risk factor for these oil and gas companies, leads us to form one final variable, $(D_{Day})(D_C)$(OPV). If the returns for hurricanes with landfalls (within the oil and gas corridor) occurring on Tuesday through Saturday are, in fact more negative, then ($\beta_4<0$).

Table 3 (Table 4) reports the regression results using market model abnormal returns (market adjusted abnormal returns). We use abnormal returns for days (-1, 0) and day (-1), the day(s) we believe we will find the most significant results given the results from Table 2, as the dependent variable. We also use the separate abnormal returns from day (0) as the dependent variable for completeness since we find the combination of days (-1, 0) to be significant. Lastly, we include abnormal returns for the three-day window, days (-1, +1), because there is some indication that some reversal of the days (-1, 0) effects may be occurring (see days (-1, +1) on Panels B and C of Table 2). Panel A of both Tables 3 and Table 4 use the least noisy observations by excluding those hurricanes with Sunday and Labor Day landfalls (16 hurricanes). Panel B of Tables 3 and 4 includes all twenty-one hurricanes.

On Panel A of Table 3 for the days (-1, 0) abnormal returns we find an overall significant model with an F-statistic of 18.96 (p=1%) and R^2 and adjusted R^2 are both greater than 80%. The coefficient on the dummy variable, D_{WSJ}, is positive, as expected, and significant (p=1%). The estimated coefficient on OPV, β_2, is positive and significant (p=1%). The coefficients on our two oil and gas corridor variables, (D_C)(OPV) and $(D_{Day})(D_C)$(OPV), are both negative as expected and significant at the p=1% and p=5% levels respectively. The results on Panel A of Table 4 (market adjusted abnormal returns as the dependent variables) for days (-1, 0) are virtually identical in all respects to those discussed from Panel A of Table 3.

Combining the coefficients on OPV yields the following insights: (1) for those hurricanes that came ashore outside the oil and gas corridor the coefficient on OPV, β_2, is positive (0.0010 on Table 3 and 0.0012 on Table 4) indicating that returns are positively related to OPV, (2) for those hurricanes that threatened the oil and gas corridor and came ashore Tuesday through Saturday the combined coefficient on OPV, ($\beta_2 + \beta_3 + \beta_4$) is negative (-0.003 on Table 3 and -0.0002 on Table 4) indicating that more variability during the period of the hurricane lowered returns, and (3) for those hurricanes with Monday landfalls that began to threaten the oil and gas corridor when the stock market was closed, thus making the day (-1) abnormal returns a noisy signal of the hurricanes' effect on market prices, the combined coefficient on OPV ($\beta_2 + \beta_3$) is positive (0.0002 on Table 3 and 0.0003 on Table 4).

We do not provide tests for the combined coefficients, some of which could combine to be insignificant from zero, in particular the hurricanes that came ashore on Monday that threatened the oil and gas corridor while the market was closed. However, the individual significance of these coefficients shows that the returns observed for hurricanes with landfalls within the oil and gas corridor are significantly lower than those observed for hurricanes with landfalls outside the oil and gas corridor. This result combined with the results from our univariate tests on Table 2 leads us to believe that when the hurricanes threatened the oil and gas corridor on Tuesday through Saturday not only were the returns significantly negative (Table 2 results) but also significantly different from those observed when a hurricane came ashore outside the oil and gas corridor.

The results for day (-1), the day on which the univariate tests identified significantly negative returns for the hurricanes that came ashore within the oil and gas corridor, are also quite significant. F-statistics for both the market model and the market adjusted abnormal returns are significant at the p=1% level. R^2 (87.1% on Table 3 and 84.9% on Table 4) and adjusted R^2 (82.4% on Table 3 and 79.5% on Table 4) remain high. As expected, the coefficient on D_{WSJ} is positive and significant (p=1%) when both market model and market adjusted abnormal returns are used the dependent variable. The coefficients for the $(D_{Day})(D_C)$(OPV) variable are negative, as expected, and significant at the p=5% level. Both of the estimated coefficients on the (D_C)(OPV) variable are negative (-0.0004 on Table 3 and -0.0005 on Table 4), as expected, and they are both significant (p=10% on Table 3 and p=5% on Table 4). Similarly, both of the estimated coefficients on OPV are positive (0.0003 on both Tables 3 and 4) and significant (p=10% on Table 3 and p=5% on Table 4).

Now, combining the coefficients on OPV yields slightly different insights than the days (-1, 0) estimations: (1) for those hurricanes that came ashore outside the oil and gas corridor the coefficient on OPV, β_2, is positive (0.0003 on both Tables 3 and 4) indicating that returns are positively related to OPV, (2) for those hurricanes that threatened the oil and gas corridor and came ashore Tuesday through Saturday, the combined coefficient on OPV ($\beta_2 + \beta_3 + \beta_4$) is lower or more negative (-0.0006 on Table 3 and -0.0007 on Table 4) than it appeared for days (-1, 0) indicating that more variability on the single day identified as the most negative with respect to the impact of a threatening hurricane lowered returns the most, and (3) for those hurricanes that threatened the oil and gas corridor when the stock market was closed, the combined coefficient on OPV ($\beta_2 + \beta_3$) is also negative (-0.0001 on Table 3 and -0.0002 on Table 4) indicating that OPV has a positive impact on returns.

The results for the day (0) abnormal returns also provide some interesting insights. First, while the estimations in total remain significant, both F-statistics remain significant at the p=1% level, the explanatory power is falling. R^2 (65.4% on Table 3 and 73.3% on Table 4) and adjusted R^2 (52.8% on Table 3 and 63.6% on Table 4) though falling, remain high. As might be expected, the D_{WSJ} coefficient becomes insignificant on both Tables 3 and 4 indicating that the news contained in the *Wall Street Journal* stories concerning the oil and gas industry is no longer affecting abnormal returns. The coefficients on the $(D_{Day})(D_C)$(OPV) variable have become zero, and thus insignificant on both Tables 3 and 4. The coefficients on the OPV variable remain positive and both are now significant at the p=1% level. The β_3 estimates (-0.0004 on both Tables 3 and 4) remain significant on Table 4 (p=10%) but become insignificant on Table 3.

Combining the coefficients on OPV for day (0) leads to new insights: (1) for those hurricanes that came ashore outside the oil and gas corridor the coefficient on OPV, β_2, is positive and now larger (0.0008 on Table 3 and 0.0009 on Table 4) than observed for day (-1), (2) for those hurricanes that threatened the oil and gas corridor and came ashore Tuesday through Saturday the combined coefficient on OPV, ($\beta_2 + \beta_3 + \beta_4$) is no longer negative (0.0008 on Table 3 and 0.0005 on Table 4) indicating that the negative returns to the hurricane threat have now dissipated on day (0), and (3) for those hurricanes that threatened the oil and gas corridor when the stock market was closed the combined coefficient on OPV ($\beta_2 + \beta_3$) is now no different than that observed for hurricanes that came ashore on Tuesday through Saturday.

The addition of a "non-event" day, day (+1) to the abnormal returns for days (-1, 0) has, as would be expected, very little impact on the estimated coefficients from the days (-1, 0) estimations. In essence, the additional returns for day (+1) add noise to our overall abnormal returns. Thus, the F-statistic, R^2, and adjusted R^2 are lower than observed for the days (-1, 0) estimations. However, our general conclusions remain intact. OPV appears to behave like a "risk factor". Returns for days with potentially bad news events, i.e. hurricanes threatening the oil and gas corridor, appear to be lower for periods when OPV is the greatest.

The estimations reported in Panel B of Tables 3 and 4 re-estimate the previous regressions but include the returns for all twenty-one hurricane events. As expected, the introduction of the noisy returns from hurricanes with landfalls on Sunday and Labor Day cause the models to lose some of their overall significance as evidenced by lower F-statistics, R^2 and adjusted R^2 in all cases than the corresponding sixteen hurricane estimations found in Panel A of Tables 3 and 4. However, our general conclusions remain valid: (1) the news effect of the *Wall Street Journal* story appears on day (-1) but dissipates completely by day (0), (2) OPV would seem to be a significant explanatory variable for the returns to our oil and gas portfolios, at least for the periods we examine, and (3) the threat of a hurricane in the oil and gas corridor in conjunction with OPV leads to significantly lower returns than for hurricanes that came ashore outside the oil and gas corridor and thus never threatened the oil and gas facilities located in the Gulf.

5. Summary and Conclusions

This research examines the possible impact of impending hurricane threats along the Gulf Coast to the oil and gas supply chain on oil and gas company portfolio returns. We find that there are significant negative abnormal returns when major hurricanes threaten the Gulf Coast areas in which the vast majority of oil and gas facilities reside (oil and gas corridor). We are unable to find significant returns for our oil and gas portfolios when Gulf Coast hurricanes do not threaten the oil and gas corridor. We show that in measuring the market's response to impending hurricanes the day of the week that the major hurricane threat presents itself must also be considered. Our regression results reveal a significant relationship between the abnormal returns and oil price volatility. We also find that as the hurricane threatens the oil and gas corridor the coefficient on oil price volatility becomes negative indicating that more volatility when a potentially bad news event is occurring causes returns to be more negative than when the threat comes in a low volatility period. Finally, the reaction to an impending threat to the oil and gas supply chain does not occur until there is a viable forecast that the threat actually exists, as evidenced by the observed significantly negative day (-1) abnormal returns.

The results indicate that the stock market is aware of potential disruptions to the oil and gas supply chain before these threats are announced by company management. Not only is the market aware of this pending threat, but it also attempts to revise stock values downward in anticipation of a potential loss. These results indicate that the stock market considers the supply chain to be more important to the value creation process than has been shown by previous research. Is the pre-emptive market reaction we identify justified? For the two most recent major hurricanes, Hurricanes Katrina and Rita in 2005, it has been reported that 115 drilling platforms were destroyed, another 52 were severely damaged, and 650 pipelines were disrupted resulting in multi-billion dollar losses from these two hurricanes (Larsen 2008). Losses of this magnitude would seem sufficient for the market to attempt to estimate these losses using the best available information for the likelihood of these losses occurring.

References

Aloui, C., R. Jammazi. 2009. The Effects of Crude Oil Shocks on Stock Market Shifts Behaviour: A Regime Switching Approach. *Energy Economics* **31**(5) 789-799.

Chen, N. F., R. Roll, S. A. Ross. 1986. Economic Forces and the Stock Market. *The Journal of Business* **59**(3) 383-403.

Cong, R. G., Y. M. Wei, J. L. Jiao, Y. Fan. 2008. Relationships between Oil Price Shocks and Stock Market: An Empirical Analysis from China. *Energy Policy* **36**(9) 3544-3553.

Ferderer, J. P. 1996. Oil price volatility and the macroeconomy. *Journal of Macroeconomics* **18**(1) 1-26.

Franklin, J. L. 2006. 2005 National Hurricane Center forecast accuracy report. http://www.nhc.noaa.gov/verification/verify3.shtml.

Gall, R., D. Parsons. 2006. It's hurricane season: Do you know where your storm is? *IEEE Spectrum* **43**(8) 27-39.

Goldsmith, J. 1995. Oil companies are expected to post gains --- Quarterly operating profits rise 20%, analysts say, despite chemical woes. *The Wall Street Journal* (October 3).

Hendricks, K. B., V. R. Singhal. 2003. The effect of supply chain glitches on shareholder wealth. *Journal of Operations Management* **21**(5) 501-522.

Hendricks, K. B., V. R. Singhal. 2005a. Association between supply chain glitches and operating performance. *Management Science* **51**(5) 695-711.

Hendricks, K. B., V. R. Singhal. 2005b. An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations Management* **14**(1) 35-52.

Jones, C. M., G. Kaul. 1996. Oil and the stock markets. *Journal of Finance* **51**(2) 463-491.

Knabb, R. D., J. R. Rhome, D. P. Brown. 2006. Tropical cyclone report: Hurricane Katrina. http://www.nhc.noaa.gov/2005atlan.shtml.

Lang, L. H. P., R. Stulz. 1992. Contagion and competitive intra-industry effects of bankruptcy announcements. *Journal of Financial Economics* 32 45-60.

Larsen, T. 2008. The energy sector's next top model. *Risk Management* **55**(1) 10.

Laux, P., L. T. Starks, P. S. Yoon. 1998. The relative importance of competition and contagion in intra-industry information transfers: An investigation of dividend announcements. *Financial Management* **27**(3) 5-16.

Lee, K., S. Ni, R. A. Ratti. 1995. Oil shocks and the Macroeconomy. *Energy Journal* **16**(4) 39-56.

Papapetrou, E. 2001 Oil price shocks, stock market, economic activity and employment in Greece. *Energy Economics* **23**(4) 511-532.

Park, J., R. A. Ratti. 2008. Oil Price Shocks and Stock Markets in the U.S. and 13 European Countries. *Energy Economics* **30**(5) 2587-2608.

Regnier, E. 2007. Oil and energy price volatility. *Energy Economics* **29**(4) 405-427.

Regnier, E. 2008. Public evacuation decisions and hurricane track uncertainty. *Management Science* **54**(1) 16-28.

Sadorsky, P. 1999. Oil price shocks and stock market activity. *Energy Economics* **21**(5) 449-469.

Winans, R. F. 1983. Analysts see rise in earnings for oil industry but split over which sectors to recommend. *The Wall Street Journal* (August 15).

Figure 1

Approximate Landfalls of Gulf Coast Major Hurricanes from 1961-2005
and Region in which Gulf Coast Oil and Gas Production Facilities are Concentrated

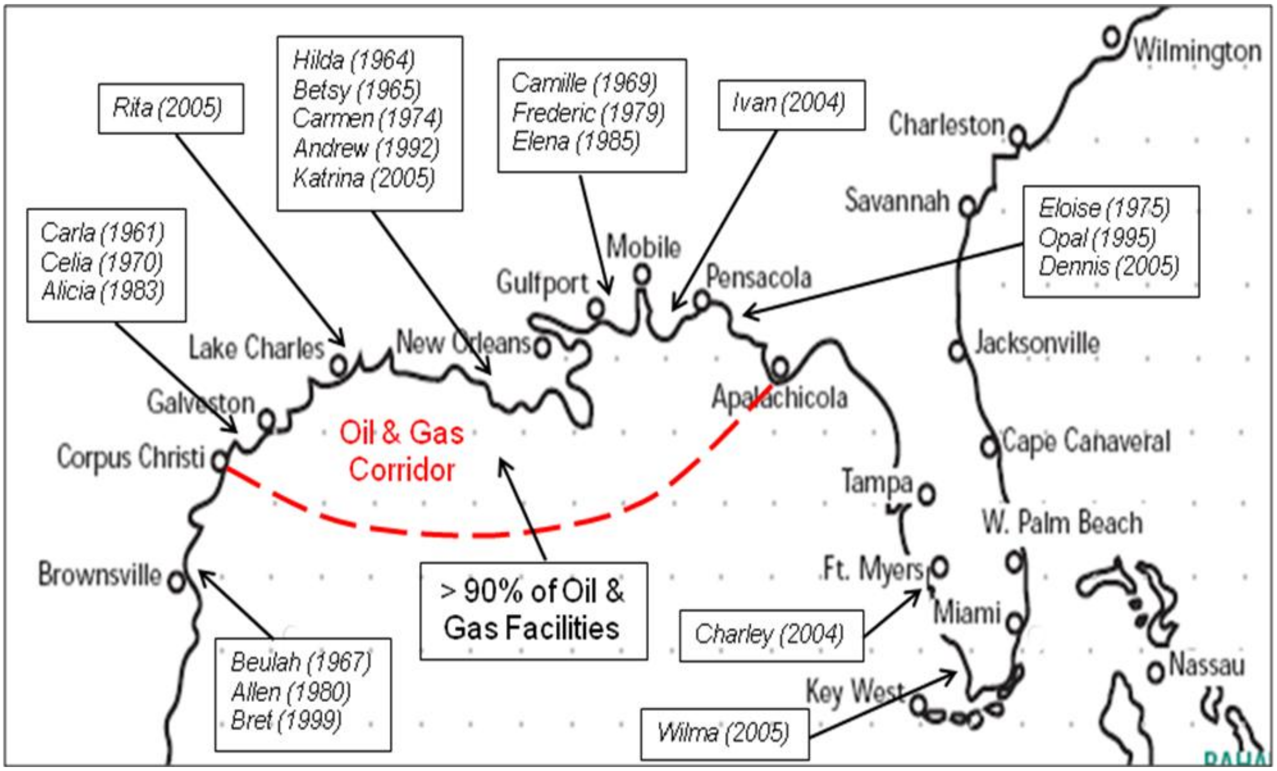

Table 1 **Major Hurricanes (Category 3 and Higher at Landfall) – 1961 to 2005**

Panel A – Landfalls within the Corpus Christi to Apalachicola Corridor:

Hurricane	Date of Landfall	Landfall Category	Day of Landfall	# Days as Gulf Hurricane	# Firms in Portfolio	Portfolio Avg. Beta
Carla	Sept. 11, 1961	4	Monday	4	19	0.88
Hilda	Oct. 3, 1964	3	Saturday	4	29	0.79
Betsy	Sept. 9, 1965	3	Thursday	2	28	0.89
Camille	Aug. 17, 1969	5	Sunday	3	25	1.04
Celia	Aug. 3, 1970	3	Monday	3	25	1.15
Carmen	Sept. 8, 1974	3	Sunday	3	27	1.06
Eloise	Sept. 23, 1975	3	Tuesday	2	27	0.91
Frederic	Sept. 13, 1979	3	Thursday	4	25	1.11
Alicia	Aug. 18, 1983	3	Thursday	2	22	0.93
Elena	Sept. 2, 1985	3	Monday	5	19	0.51
Andrew	Aug. 26, 1992	3	Wednesday	3	18	0.48
Opal	Oct. 4, 1995	3	Wednesday	3	19	0.47
Ivan	Sept. 16, 2004	4	Thursday	3	12	0.71
Dennis	July 10, 2005	3	Sunday	2	12	1.02
Katrina	Aug. 29, 2005	3	Monday	4	12	1.05
Rita	Sept. 24, 2005	3	Saturday	4	11	1.05

Panel B - Landfall south of Apalachicola:

Hurricane	Date of Landfall	Landfall Category	Day of Landfall	# Days as Gulf Hurricane	# Firms in Portfolio	Portfolio Avg. Beta
Charley	Aug. 13, 2004	4	Friday	1	11	0.65
Wilma	Oct. 24, 2005	3	Monday	2	11	0.99

Panel C - Landfall south of Corpus Christi:

Hurricane	Date of Landfall	Landfall Category	Day of Landfall	# Days as Gulf Hurricane	# Firms in Portfolio	Portfolio Avg. Beta
Beulah	Sept. 20, 1967	3	Wednesday	4	28	0.93
Allen	Aug. 10, 1980	3	Sunday	3	25	1.59
Bret	Aug. 23, 1999	3	Monday	4	17	0.47

Table 2 **Abnormal Stock Returns for Major Hurricanes with Landfalls on the U.S. Gulf Coast**

Panel A: All Major Hurricanes (21 in total) with Landfalls on the U.S. Gulf Coast

Mean Percentage Market Model Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.19	-0.02	-0.06	0.09	0.32	0.07	0.07	0.03	0.34	0.39	0.64

Mean Percentage Market Adjusted Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.18	0.07	0.03	0.13	0.29	0.08	0.08	0.16	0.45	0.59	0.83

Panel B: Major Hurricanes (10 in total) with Landfalls within the Oil and Gas Corridor (Excludes Hurricanes with Sunday and Labor Day Landfalls)

Mean Percentage Market Model Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.65	0.01	**-0.52*****	-0.07	0.45	0.45	0.43	**-0.60*****	-0.14	0.30	1.35

Mean Percentage Market Adjusted Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.66	0.12	-0.47	-0.05	0.45	0.48	0.46	**-0.52*****	-0.07	0.52	1.61

Panel C: Major Hurricanes (7 in total) with Landfalls within the Oil and Gas Corridor (Excludes Hurricanes with Sunday and Monday Landfalls)

Mean Percentage Market Model Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.81	0.14	**-0.63****	0.01	0.30	0.32	0.25	**-0.63****	-0.33	0.13	1.18

Mean Percentage Market Adjusted Abnormal Returns

Individual Days							Accumulation Windows			
-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**(-1, 0)**	**(-1, +1)**	**(-2, +2)**	**(-3, +3)**
0.81	0.26	-0.58	-0.01	0.29	0.33	0.26	**-0.58****	-0.30	0.30	1.37

Notes:
Wilcoxon Two-Tail Significance Level: ** p = 5%; *** p = 1%

Table 3 **Regression Results – Market Model Abnormal Returns**

$$AR = \alpha + \beta_1 D_{WSJ} + \beta_2 OPV + \beta_3 (D_C)(OPV) + \beta_4 (D_{Day})(D_C)(OPV) + \varepsilon$$

Panel A: Major Hurricanes (16 in total) with Landfalls on the U.S. Gulf Coast (Excludes Hurricanes with Sunday and Labor Day Landfalls)

	Days (-1, 0)	Day (-1)	Day (0)	Days (-1, +1)
Constant	-0.0041**	-0.0005	-0.0036*	-0.0009
D_{WSJ}	0.0227***	0.0211***	0.0015	0.0216***
OPV	0.0010***	0.0003*	0.0008***	0.0015***
$(OPV)(D_C)$	-0.0008***	-0.0004*	-0.0004	-0.0008**
$(OPV)(D_C)(D_{Day})$	-0.0005**	-0.0005**	0.0000	-0.0010**
F-Statistic	18.96***	18.60***	5.20***	11.15***
R^2	87.3%	87.1%	65.4%	80.2%
Adjusted R^2	82.7%	82.4%	52.8%	73.0%

Panel B: All Major Hurricanes (21 in total) with Landfalls on the U.S. Gulf Coast

	Days (-1, 0)	Day (-1)	Day (0)	Days (-1, +1)
Constant	-0.0023	0.0012	-0.0035**	-0.0011
D_{WSJ}	0.0215***	0.0020***	0.0015	0.0217**
OPV	0.0010***	0.0002	0.0008***	0.0013***
$(OPV)(D_C)$	-0.0013***	-0.0006***	-0.0006***	-0.0014***
$(OPV)(D_C)(D_{Day})$	-0.0001	-0.0003	-0.0003	-0.0003
F-Statistic	10.78***	13.73***	6.45***	6.13***
R^2	72.9%	77.4%	61.7%	60.5%
Adjusted R^2	66.2%	71.8%	52.1%	50.6%

Notes:
D_{WSJ} = Dummy => Equals 1 for Hurricanes Alicia and Opal, 0 otherwise
OPV = Oil Price Volatility => Standard Deviation of Oil Prices for the 30 months prior to the Hurricane
D_C = Dummy => Equals 1 if Landfall was within the Oil and Gas Corridor, 0 otherwise
D_{Day} = Dummy => Equals 1 if Landfall occurred on Tuesday through Saturday, 0 otherwise

All t-tests are two-tail and significance levels are: * p = 10%; ** p = 5%; *** p = 1%

Table 4 **Regression Results – Market Adjusted Abnormal Returns**

$$AR = \alpha + \beta_1 D_{WSJ} + \beta_2 OPV + \beta_3(D_C)(OPV) + \beta_4(D_{Day})(D_C)(OPV) + \varepsilon$$

Panel A: Major Hurricanes (16 in total) with Landfalls on the U.S. Gulf Coast (Excludes Hurricanes with Sunday and Labor Day Landfalls)

	Days (-1, 0)	Day (-1)	Day (0)	Days (-1, +1)
Constant	-0.0044**	-0.0003	-0.0041**	-0.0018
D_{WSJ}	0.0235***	0.0214***	0.0021	0.0213***
OPV	0.0012***	0.0003**	0.0009***	0.0017***
$(OPV)(D_C)$	-0.0009***	-0.0005**	-0.0004*	-0.0009**
$(OPV)(D_C)(D_{Day})$	-0.0005**	-0.0005**	0.0000	-0.0010**
F-Statistic	22.00***	15.50***	7.54***	14.10***
R^2	88.9%	84.9%	73.3%	83.7%
Adjusted R^2	84.9%	79.5%	63.6%	77.7%

Panel B: All Major Hurricanes (21 in total) with Landfalls on the U.S. Gulf Coast

	Days (-1, 0)	Day (-1)	Day (0)	Days (-1, +1)
Constant	-0.0025	0.0014	-0.0039**	-0.0018
D_{WSJ}	0.0222***	0.0203***	0.0020	0.0213***
OPV	0.0012***	0.0003	0.0009***	0.0015***
$(OPV)(D_C)$	-0.0014***	-0.0007***	-0.0007***	-0.0014***
$(OPV)(D_C)(D_{Day})$	-0.0001	-0.0003	0.0002	-0.0004
F-Statistic	13.43***	12.27***	9.49***	8.42***
R^2	77.1%	75.4%	70.3%	67.8%
Adjusted R^2	71.3%	69.3%	62.9%	59.7%

Notes:
D_{WSJ} = Dummy => Equals 1 for Hurricanes Alicia and Opal, 0 otherwise
OPV = Oil Price Volatility => Standard Deviation of Oil Prices for the 30 months prior to the Hurricane
D_C = Dummy => Equals 1 if Landfall was within the Oil and Gas Corridor, 0 otherwise
D_{Day} = Dummy => Equals 1 if Landfall occurred on Tuesday through Saturday, 0 otherwise

All t-tests are two-tail and significance levels are: * p = 10%; ** p = 5%; *** p =1%