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West Texas Intermediate and Brent Spread during Organization of the Petroleum Exporting Countries Supply Disruptions

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ABSTRACT

This paper investigates the price spread between West Texas Intermediate and Brent during periods of supply disruptions. Using a sample of 50 events of Organization of the Petroleum Exporting Countries (OPEC) - related unplanned upstream production outages, this paper documents a statistically significant tightening in the price differential. The finding is robust even after accounting for 22 OPEC - related political conflicts, 104 extreme weather conditions in the Atlantic basin, and the period of infrastructural bottlenecks in and around the Cushing, Oklahoma. The result is further confirmed when examining the spread between Light Louisiana sweet and Brent. These findings suggest the need to hedge against such risks and give rise to speculative trading which can be facilitated using the vibrant paper markets.

Keywords: Crude Oil, Benchmarks, Organization of the Petroleum Exporting Countries, Supply Disruptions
JEL Classifications: G12, Q34, Q41

1. INTRODUCTION

The collapse of crude oil prices in the mid-1980s, and the events leading to it, ushered in the demise of the Organization of the Petroleum Exporting Countries (OPEC) - administered pricing system and heralded a transition towards a market-based regime. Necessary to the revolutionizing of the system has been the emergence of vibrant spot and paper markets which enhanced both transparency and price formation processes. At the heart of these developments has been the concept of formula-based pricing in which reference crudes, such as Brent, West Texas Intermediate (WTI), or Dubai/Oman, play a vital role.

In its simplest form, the formula-based system prices a grade of crude oil off a benchmark price by adding or subtracting a differential. Factors such as the quality of the grade relative to that of the benchmark, the prices of competing grades, gross product worth,[1] and time and location will all determine the size of the differential. Notwithstanding the significance of a benchmark's outright price, this paper aims at examining the spread between the respective prices of these reference crudes. A number of factors render such an examination its importance.

First of all, the essence of the formula pricing system is built around price relationships rather than outright prices; therefore spread trading is the tool through which most of crude oil grades are traded in the market (Energy Intelligence, 2011). Secondly, spreads or differentials between the various traded crudes are a vital issue for risk management from the point of view of producers, exporters, importers and traders (Mabro, 2005). Thirdly, futures markets provide oil traders with the opportunity to hedge against adverse movements in price differentials. Additionally, speculative investors can exploit potential changes in oil price spreads by taking positions in futures contracts. For example, both the New York Merchantile Exchange (NYMEX) and Intercontinental Exchange (ICE) offer futures and options contracts with the WTI-Brent spread being the underlying asset.

1 Gross Product Worth (GPW) is the value of refined products at the market. GPW will differ among crudes since each crude has its own natural yield of petroleum products. Crude Assays are reports published by producers listing the main characteristics of their crudes including natural yields. Additionally, the yield will differ depending on the refining process. Please see Fattouh (2011) and Energy Intelligence (2011) for in-depth discussion of evolution of the crude oil pricing regime.

Thus, investigating the behavior of crude oil spreads is a matter of interest for academics, commercial and speculative traders.

Moreover the relative prices of benchmarks, as reflected in their spread, matter for an importing country whose crude imports are not priced-off one reference crude; with the US market setting a good example. The spread would matter not only for refiners in an importing country, but also for policy makers in relation to the security of supply and cost of building up strategic reserves. In this vein, Yaprakli and Kaplan (2015) show that disruptions to oil supplies are among the important exogenous events that could significantly affect demand for oil from an importing nation. Similarly, an oil producer whose exports are destined into one market where more than one benchmark is used could be interested in the spread between these reference crudes.

The above considerations lead this paper to examine the fluctuation of the WTI-Brent spread in the vicinity of 50 OPEC-related unplanned production outages between 1987 and 2012. The findings show that periods of unplanned outages are associated with statistically significant tightening in the WTI-Brent Spread. The narrowing in the price differential is further confirmed after accounting for other political conflicts, extreme weather conditions, and the period of infrastructural constraints. The results are robust when examining the price differential between Brent and Light Louisiana sweet (LLS), the de facto light and sweet crude benchmark in the US Gulf Coast (Argus, 2012; Energy Intelligence, 2011). Moreover, the findings attest to the importance of the costs of logistics and stocks of crude oil and petroleum products in shaping the spread between the benchmarks.

The paper is organized as follows: the next subsection provides an overview of the crude oil pricing regime and introduces the two reference crudes, Brent and WTI. Subsection 1.2 reviews the literature. The data, methodology, and descriptive statistics are presented in Section 2. Section 3 discusses the results and the robustness tests, while Section 4 concludes the paper by discussing the relevance of its findings and the implications to various parties.

1.1. Crude Oil Pricing Regime and the Role of Benchmarks

Although the use of formula pricing was initially introduced in 1986 by the Mexican National Oil Company PEMEX, the role of a reference price has existed since the late 1970s and early 1980s (Fattouh, 2011; Energy Intelligence, 2011; Mabro, 2005). That period witnessed the emergence of the Saudi Arab Light as the reference crude in the OPEC-administered pricing system, and Forties and later Brent as the North Sea's benchmark (Energy Intelligence, 2011).

The introduction of markers and the gradual emergence of spot trading required crudes that are characterized by their high production volume, security of supply, consistent quality and diversity of sellers (Energy Intelligence, 2011). The events of 1986 had led to a market environment in which Brent and WTI were chosen as international reference crudes, because they held the necessary characteristics of a benchmark and had a well-established spot and paper markets to allow for a relatively transparent trading.

Brent is a light and low sulphur blend of crudes which is produced from offshore fields in the North Sea.[2] Brent is the primary reference grade in the global oil market as on daily basis it is benchmarking two thirds of physically traded oil on both spot and term-contract basis (ICE, 2013; Fattouh, 2011; Energy Intelligence, 2011). Its spot, forward, and futures markets are mutually dependent and their linkages form the Brent pricing complex (Energy Intelligence, 2011). Dated Brent refers to the spot market of the Brent complex and virtually all the trades in the European and African spot markets are linked to the dated Brent price (Energy Intelligence, 2011). Moreover, supplies sold into European markets on term-contract basis are also priced off dated Brent; while sales of African crudes into the US are directly or indirectly linked to the Brent pricing complex (Fattouh, 2011; Energy Intelligence, 2011).

WTI is the chief benchmark for pricing imports of the fossil fuel into the market of the largest consumer and importer of oil in the world, the United States (Eni, 2012; Fattouh, 2011). WTI is a blend of US domestic crudes of high quality; with an American Petroleum Institute (API) gravity of 39° and sulphur content of 0.45% rendering it a light and sweet blend (Energy Intelligence, 2011. p. 92; CME Group, 2013). Unlike Brent which is waterborne, WTI is transported via pipelines and deliveries of its cargos take place at the US major storage center at Cushing (CME Group, 2013; Fattouh, 2011; Energy Intelligence, 2011). WTI has been the reference grade underlying the NYMEX light and sweet futures contracts since 1983. These trading instruments not only enhanced the visibility of a rather landlocked crude, but also increased the transparency of its price formation process (Fattouh, 2011; Energy Intelligence, 2011). Open interest in the NYMEX light and sweet futures contracts has increased from 121,428 in December 1987 to 1,473,345 contracts in the same month of 2012.[3]

1.2. Literature Review

As mentioned earlier, formula pricing is at the heart of the current pricing system, which in turn points to the importance of differentials among the prices of the various competing crudes in the oil market. Despite that, the investigation of these interrelationships attracted relatively little academic attention. Additionally, the area that occupies the lion share of empirical investigations is that exploring the extent of regionalization versus unification of oil markets.

The question of the regionalization of oil markets originates from Weiner (1991) who examines the claim that the oil market is "one great pool" (Adelman, 1984. p. 5). Weiner hypothesizes that if oil markets were fragmented, then prices of the same crude arising in different regions would move independently. In such markets, the cost of transportation would be larger than regional price differentials, thus hindering adjustments through arbitrage. By examining prices of six different grades of crude oil in five geographical regions, Weiner shows a strong evidence of regionalization in oil markets. However, this evidence is

2 Brent blend has an API gravity of 38.5° and sulphur content of 0.41%. Full Brent Assay on: www.exxonmobil.com

3 Commitments of Traders, US Commodity Futures Trading Commission: www.cftc.gov

inconclusive for that subsequent empirical research provides evidence supporting the "one great pool" hypothesis (Gülen, 1999; Ewing and Harter, 2000; Bentzen, 2007; Hammoudeh et al., 2008; and Fattouh, 2010), or documents an accelerated move towards unification (Kleit, 2001). It is worth noting that while the latter papers utilize data mostly from the 1990s onwards, Weiner (1991) examines the period from 1980 to 1987 which preceded the inception of the current pricing regime.

Further insights into the nature of interrelationship between WTI and Brent are provided by investigating spillover effects between their markets. In an attempt to explore the leader market, Lin and Tamvakis (2001) investigate information transmission mechanism between NYMEX and International Petroleum Exchange (IPE) (later ICE) futures markets. When considering over-lapping trading between the two markets, Lin and Tamvakis document spillover effects running in both directions. Interestingly, they point out the leading role of WTI by showing that up to 2 previous days of NYMEX's trading-related information affect IPE's Brent futures when non-lapping trading is considered.

However, WTI's leading role has been questioned since 2007. This is due to the accumulation of historical stock levels at Cushing and infrastructural bottlenecks which hindered the movement of oil to the major refining center in the US Gulf Coast (Fattouh, 2011; Energy Intelligence, 2011; Hammoudeh et al., 2008). Kao and Wan (2012) document the dramatic retreat of WTI's role as a benchmark relative to Brent over time. Specifically, they show that during periods of WTI-related contango and discount to Brent, the US benchmark's ability to process news deteriorates; while Brent dominates the information-share.

The lack of evidence on the behavior of the spread between the two most prominent benchmarks during periods of unplanned production outages and political conflicts comes as a surprise. This is despite the interwining history of oil shocks and geopolitical events (Hamilton, 2011; Darbouche and Fattouh, 2011) and the significant role that the fossil fuel has been playing in propelling the war machine since World War I (Yergin, 2012). Deloitte (2009), for example, estimates US military consumption of fuel in Iraq and Afghanistan to stand at 22 gallons per soldier per day; a staggering 175% increase from its level in the Vietnam conflict.

The literature has not been silent, though, on the effect of wars on the outright price of crude oil. Omar et al. (2013) examine the behavior of WTI prices on and around the trigger dates of 64 international conflicts and a sub-sample of 43 violent crises. They document a significant positive abnormal return for the US benchmark during these events, and further show that the fossil fuel can act as a safe haven for investors in US and international stock markets during such episodes. Similar findings on the impact of wars are found in Leigh et al. (2003) and Rigobon and Sack (2005) who both show a surge in oil prices due to the heightened risk of the war in Iraq.

The paper aims to address a gap in the literature by examining the behavior of the WTI-Brent price differential on and around 50 events of unscheduled outages in OPEC's production. By doing so, the paper contributes to the existing literature on crude oil spreads, and offers insights into the interrelationship between the world's most prominent benchmarks.

2. DATA, METHODOLOGY, AND DESCRIPTIVE STATISTICS

2.1. Data

The paper uses end of month data from May 1987 to December 2012 on the prices of three grades of oil and a number of explanatory variables. The year 1987 is chosen as it followed the dramatic collapse of oil prices, Saudi refusal to act as swing producer and the ultimate change in OPEC's policy from defending its marker price to protecting its market share (Kaufmann et al., 2004; Yergin, 2012). The availability of data on the prices of dated Brent dictates the choice of the starting month. Monthly observations are chosen due to explanatory variables which are not available with higher sampling frequencies.

The dataset consists of spot prices of WTI for delivery in Cushing; free on board (FOB) dated Brent prices, and spot prices of LLS. All prices are in US dollar. Additional US-based explanatory variables are utilized in the analysis. These include the industrial production index; crude oil stocks excluding strategic petroleum reserves (SPRs); finished motor gasoline stocks; distillates stocks; residual fuel stocks; US dollar cost of refinery acquisition of imported crude oil and US dollar FOB and landed costs of imported oil. The availability of data dictates the use of US-based control variables.

The data is taken from four sources. Prices of both WTI and Brent are sourced from Datastream, while LLS prices are taken from Bloomberg. The Federal Reserve Bank of St. Louis Economic Data is the source of data on US industrial production. Data on FOB and landed costs of imported crudes, refinery acquisition cost of imported crudes, and stocks of crude oil and products are all sourced from the Energy Information Administration.

The sample of OPEC-related unplanned production disruptions is sourced from Bloomberg. The paper considers dates on which unscheduled outages in upstream production occurred. Such events may rise due to unexpected extreme weather conditions; explosions; oil leak or spill; strikes; acts of sabotage; and terrorism and wars. Since such reasons, even when unforeseen, still may not result in a production outage, the paper considers only these events which led to an explicit announcement of disruption. The announcement may take the form of a shutdown in certain units which brings production to a partial or full halt. Additionally, a producer may declare a force majeure, which is the state in which an oil company will not be able to meet its contractual obligations of delivering the agreed upon shipments of crude, due to events beyond its control.

The Bloomberg terminal contains the function NI FIELDOUT which is designed to provide news on oil, natural gas field outages and allows users to scroll through these pieces of news. This function also offers the ability to filter news by key words, source, language and date. The extraction of dates on which unplanned production disruptions occurred follows the procedure described below. First of all, English is the language utilized, and the source of news is "all." Secondly, news is filtered on the basis of each of OPEC's members. Thirdly, for each member country, dates are further filtered by the range of dates considered in this paper (i.e. May 1987 to December 2012). Finally, only news which explicitly states the occurrence of unscheduled disruption is considered. Total number of dates on which such events occurred are 93 between 1987 and 2012.

Since the paper employs monthly data, the dates on which disruptions occurred must also be aggregated to monthly observations. For example, during November 2012, Eni, Shell and Exxon have all announced unscheduled disruptions in their Nigerian operations on 3 different days. These are all dealt with as one event pertaining to November of that year. Thus, the aggregation reduces the number of events from 93 to 50 events of unscheduled production outages.

Finally, and as a part of robustness tests, I construct two samples comprising two different set of events which may have explanatory power. The first contains the start dates of 22 events of OPEC-related political crises which did not coincide with unplanned outages in production. The International Crises Behavior project database (version 10, July 2010) is the source of 18 of these events,[4] while the remaining four are sourced from the Conflict Barometer publications of the Heidelberg Institute for International Conflict Research (HIIK).[5]

The second sample involves months during which hurricanes occurred in the Atlantic basin. Hurricanes can have a devastating impact on the US oil industry's upstream and downstream operations, as was evident in the hurricane season of 2005 and 2008 (US Department of Energy, 2009). Thus, these events may affect the price relationships between US crudes and Brent. To account for their potential impact, I source data on the months in which at least one hurricane occurred from the US National Hurricane Center's Tropical Cyclone Reports. This exercise generates 104 months between 1987 and 2012.

2.2. Methodology: modelling WTI-Brent Price Differential

In order to quantify the behavior of the WTI-Brent spread on and around unplanned production outages, I introduce an event window of 3 monthly intervals centered on the month in which a disruption occurred; called the trigger month. Additionally, I propose a number of control variables and specify the following model:

$$\begin{aligned} Sp_{\mathrm{WTI}_t-\mathrm{Brent}_t} = {} & C+\beta_1 D_{\mathrm{Outages}\ t}+\beta_2 D_{\mathrm{Autumn}\ t}+\beta_3 D_{\mathrm{Winter}\ t}+\beta_4 D_{\mathrm{Spring}\ t} \\ & +\beta_5 USIP_{t-1}+\beta_6\, Stocks_{\mathrm{Crude}_t}+\beta_7 TSIC_{t-1} \\ & +\beta_8 Sp_{\mathrm{WTI}_{t-1}-\mathrm{Brent}_{t-1}}+\varepsilon_t \end{aligned} \tag{1}$$

Where the error term ε_t is assumed to be independently and identically normally distributed with mean 0 and variance equal to σ^2. $Sp_{\mathrm{WTI}_t-\mathrm{Brent}_t}$ is the difference between the natural logarithm of the prices of WTI and Brent at time period t. $D_{\mathrm{Outages}\ t}$ is a dummy variable which takes the value 1 if it falls within the 3 months event window and 0 otherwise. $D_{\mathrm{Autumn}\ t}$, $D_{\mathrm{Winter}\ t}$ and $D_{\mathrm{Spring}\ t}$ are dummy variables which take the value 1 for months in autumn (September, October, November), winter (December, January, February) and spring (March, April, May) respectively, and 0 otherwise. $USIP_{t-1}$ is the continuously compounded percentage change in the US industrial production index between time period t and $t-1$, included with 1 month lag in order to avoid endogeneity problem.[6] $Stocks_{\mathrm{Crude}_t}$ is the continuously compounded percentage change in the US crude oil stocks excluding SPRs between time period t and $t-1$. $TSIC_{t-1}$ is transportation, storage and insurance cost of imported crude oil into the US at time period $t-1$. This cost is the difference between the natural logarithm of US refinery acquisition cost of imported crude oil and FOB and landed costs of imported crude oil. $Sp_{\mathrm{WTI}_{t-1}-\mathrm{Brent}_{t-1}}$ is the 1 monthly interval-lagged WTI-Brent log price differential.

Model (1) accounts for potential control variables which would explain the fluctuation of the WTI-Brent price differential. However, to account for the potential explanatory power of petroleum products, I additionally model the spread as a function of the US stocks of gasoline, distillates, and residual fuel. Therefore:

$$\begin{aligned} Sp_{\mathrm{WTI}_t-\mathrm{Brent}_t} = {} & C+\beta_1 D_{\mathrm{Outages}\ t}+\beta_2 D_{\mathrm{Autumn}\ t}+\beta_3 D_{\mathrm{Winter}\ t}+\beta_4 D_{\mathrm{Spring}\ t} \\ & +\beta_5 Stocks_{\mathrm{Gasoline}_t}+\beta_6 Stocks_{\mathrm{Distillates}_t}+\beta_7 Stocks_{\mathrm{Residual}_t} \\ & +\beta_8 TSIC_{t-1}+\beta_9 Sp_{\mathrm{WTI}_{t-1}-\mathrm{Brent}_{t-1}}+\varepsilon_t \end{aligned} \tag{2}$$

Where,
$Stock_{\mathrm{Gasoline}_t}$, $Stock_{\mathrm{Distillates}_t}$, $Stock_{\mathrm{Resdiual}_t}$, are the continuously compounded percentage changes in the stocks of motor gasoline, distillates and residual fuel between time t and $t-1$, respectively. The remaining variables are identical to those in model (1). Finally, in order to obtain statistically consistent estimates of the variance-co-variance matrix, I estimate model (1) and (2) using Newey-West standard errors approach.

A number of points ought to be highlighted in relation to the variables in both sides of regression equations (1) and (2). First of all, the use of difference in the natural logarithm of prices of two different crudes is evident in the literature; and it is arguably

4 I choose conflicts in which at least one OPEC member was involved. ICB codebook shows the trigger date of conflict under the code SYSDATE. The paper uses actor-level data. ICB dataset is available at: www.cidcm.umd.edu/icb/. Numerous academic studies have utilized its data (please see Omar et al., 2013, Berkman et al., 2011; Blomberg et al., 2004, in addition to many other academic papers and books that are listed on ICB web page).

5 I choose the dates on which either a conflict started, or crisis level of violence witnessed an uptick. Conflict Barometer is available at: www.hiik.de/en/konfliktbarometer/index.html

6 The inclusion of US industrial production with a one month lag is supported by the findings of Ewing and Thompson (2007). They show that the US industrial production leads the price of WTI by 1-month. Their findings concur with those of Serletis and Shahmoradi (2005) who document that natural gas prices lag US industrial production.

more appropriate to express the price differential as a percentage of the fossil fuel's price (Fattouh, 2010; Weiner, 1991). The addition of the variable $Sp_{WTI_{t-1}-Brent_{t-1}}$ in both models is to account for persistence in the price differential.

Secondly, I postulate a negative sign for the variable $D_{\text{outages t}}$ in models (1) and (2).[7] Put alternatively, the spread between the two benchmarks may tighten as a result of unplanned outages in OPEC. Brent is the benchmark of the light and sweet waterborne crudes in the Atlantic basin (ICE, 2013). Additionally, seaborne transportation accounted for two-thirds of the fossil fuel that had been transported globally in 2009 (Energy Intelligence, 2011). The importance of waterborne crudes has been demonstrated following the Arab spring and the Fukushima incident which both set upward pressure on the prices of these crudes (Büyükşahin et al., 2013).

In a stark contrast, WTI and other US domestic crudes are landlocked and heavily dependent on the pipeline infrastructure, which accounted for 70% of US crude transportation in 2009 (Association of Oil Pipe Lines, 2012). These features had made the US crudes vulnerable to infrastructural bottlenecks and pipelines-related incidents and resulted in disconnecting these crudes from global markets (Kao and Wan, 2012; Fattouh, 2011; 2010; Energy Intelligence, 2011; EIA, 1996). Disconnection from global oil markets can have significant economic costs. A case in point is the Canadian crudes which are pipelined and suffer from transportation bottlenecks. The landlocked location of Canadian crudes force producers to sell their oil at discounts to international prices with daily losses estimated at $ 50 million (Canadian Chamber of Commerce, 2013).

Thirdly, Brent destined to the US trades at a discount to WTI under normal market conditions although both crudes are of similar quality. The price structure reflects the economics of transportation which enables traders and refiners to economically import and process Brent in the US (EIA, 2013). The US market is characterized by the fierce competition that oil exporters face which forces them to incur transportation-related costs (Fattouh, 2011). This is in contrast to crudes destined to Asia where buyers would bear transportation costs; and which in turn gives rise to the "Asian Premium" (Fattouh, 2011. p. 24). In order to control for the financial aspects of logistics, I construct a rough approximation of transportation, storage and insurance cost, denoted transportation; storage and insurance cost (TSIC). This variable is constructed as the difference between the natural logarithms of refinery acquisition cost of imported crude oil and the FOB and landed costs of imported crudes. The difference between these costs yields an aggregate approximation of the costs of seaborne transportation, storage and insurance. Taking into account that these costs may depend on the spot price of the fossil fuel, the variable TSIC is incorporated in models (1) and (2) with a 1 month lag.[8]

Finally, regression equations (1) and (2) control for the potential role of crude oil and products stocks in crude oil pricing. Petroleum inventories are necessary to ensure the smooth functioning of a supply system in which inputs and outputs are delivered in batches (Energy Intelligence, 2011; Ye et al., 2002; EIA, 1996). Additionally, the fact that different grades of oil have different qualities necessitates storage in order to segregate these crudes along the supply chain (EIA, 1996). Stocks have also an important economic role as marginal source of supply, and can indicate the state of balance or imbalance in the market (Kaufmann et al., 2008; Ghouri, 2006; Ye et al., 2002; EIA, 1996).

2.3. Descriptive Statistics

Table 1 reports the summary statistics and unit root test results for the price differentials and explanatory variables in regression equations (1) and (2); while Table 2 shows the correlations between the price spreads and the right hand-side variables. Additionally, Figure 1 depicts the fluctuations of the WTI-Brent and LLS-Brent price differentials; and those of the other explanatory variables. The first noticeable observation pertains to the average log spread between WTI-Brent. Despite the deep discounts of WTI against Brent after 2007, the average differential is positive reflecting the normal relationship that ought to exist between these two benchmarks.

An additional interesting finding in Table 1 is that the average log spread between LLS and Brent exceeds that of WTI-Brent by 2%. This may reflect the fact that while WTI suffers from its landlocked location at the Cushing storage center, LLS is directly traded and processed in the US Gulf Coast which holds 48% of the country's refining capacity (Andrews et al., 2010). Table 2 reports noticeable findings on the correlations between the price spreads and explanatory variables. Both price differentials show a significant negative correlation with the variable $D_{\text{outages t}}$. This finding suggests that the price spreads tighten during periods of unplanned production disruptions. Moreover, these correlations provide a support for the hypothesis presented earlier on the potential sign of the variable $D_{\text{outages t}}$ in equations (1) and (2).

Table 2 further shows that the cost of transportation, storage and insurance has significant positive correlation with the spreads. This is expected as Brent is waterborne and its marketability in the US would be significantly affected by logistical costs. Among all petroleum stocks, only residual fuel inventories show a significant positive correlation with WTI-Brent. The graphical depiction, in Figure 1, of the WTI-Brent differential exhibits a stable relationship in which WTI trades at premium over Brent for most of the sample period. This stability changes significantly

7 The choice of including one monthly interval preceding and following the trigger month could be justified on the basis of the length of an oil tanker's voyage destined to the US from Sullom Voe in the UK. Such a voyage is estimated to require approximately 16 days to reach Corpus Christi in the US (Energy Intelligence, 2011. p. 65). Considering that this paper utilizes monthly data, a one monthly interval could be a reasonable approximation for the length of that voyage.

8 Following communication with EIA to inquire about the availability of dataset on logistics-related costs, I was informed that a rough approximation of these costs could be calculated using existing data on imports which are available on eia.gov. The approach is as explained above and follows EIA's recommendation. Additionally, please visit the aforementioned website for full definitions of the three different costs involved in constructing the variable.

Table 1: Descriptive statistics

Variables	Mean	SD	25th percentile	Median	75th percentile	Unit root
$Sp_{WTL_t-Brent_t}$	0.0403	0.0732	0.0183	0.0561	0.0845	−4.3470***
$Sp_{LLS_t-Brent_t}$	0.0627	0.0367	0.0404	0.0678	0.0834	−7.1112***
$USIP_t$	0.0018	0.0065	−0.0013	0.0024	0.0057	−4.6439***
$Stocks_{Crude\ t}$	0.0003	0.0305	−0.0218	0.0011	0.0204	−16.2439***
$Stocks_{Gasoline\ t}$	−0.0001	0.0370	−0.0228	0.0009	0.0245	−5.0046***
$Stocks_{Distillates\ t}$	0.0010	0.0633	−0.0325	0.0076	0.0466	−4.3875***
$Stocks_{Residual\ t}$	−0.0002	0.0583	−0.0387	0.0073	0.0391	−15.4306***
$TSIC_t$	0.0702	0.0566	0.0245	0.0745	0.1137	−9.1245***

This table reports descriptive statistics for crude oil spreads and control variables from May 1987 to December 2012. The price differentials, $SP_{WTL_t-Brent_t}$ and $SP_{LLS_t-Brent_t}$, are expressed as the natural logarithmic difference between respective prices of the two crudes. Transportation, storage and insurance cost, $TSIC_t$, is the logarithmic difference between refinery acquisition cost of imported oil at time t and FOB and landed costs of imported oil in the US at time t. Industrial production index in the US, $USIP_t$, and stocks of crude oil, gasoline, distillates, and residual fuel are all expressed in logarithmic difference between time t and t−1. Last column of Table 1 reports the augmented Dickey-Fuller test statistics for log price spreads and transportation, storage and insurance cost, and the first difference in log levels for remaining variables. ***,**,*Statistical signficance at 1%, 5% and 10% respectively. TSIC: Transportation; storage and insurance cost, SD: Standard deviation, FOB: Free on board

Table 2: Pearson correlations

Variables	$Sp_{WTL_t-Brent_t}$	$Sp_{LLS_t-Brent_t}$
$D_{Outages\ t}$	−0.4378 (0.0000)	−0.3178 (0.0000)
$D_{Autumn\ t}$	−0.0455 (0.4266)	0.0163 (0.7762)
$D_{Winter\ t}$	0.0207 (0.7175)	0.0490 (0.3912)
$D_{Spring\ t}$	0.0543 (0.3426)	0.0218 (0.7030)
$USIP_t$	−0.0090 (0.8750)	−0.0733 (0.1992)
$Stocks_{Crude\ t}$	0.0385 (0.5005)	0.0897 (0.1160)
$Stocks_{Gasoline\ t}$	−0.0106 (0.8537)	0.0305 (0.5936)
$Stocks_{Distillates\ t}$	0.0419 (0.4642)	0.0594 (0.2989)
$Stocks_{Residual\ t}$	0.0945 (0.0987)	0.0928 (0.1041)
$TSIC_t$	0.5071 (0.0000)	0.4340 (0.0000)

This table reports Pearson correlations between the two crude oil spreads and control variables between May 1987 and December 2012. *P* values for the correlation coefficients are given in parentheses. Price differentials and transportation, storage and insurance cost, $TSIC_t$, are the difference in natural log levels at time t. $D_{Outages\ t}$ is dummy variable which takes the value 1 in a 3 months window surrounding the month in which a production outage occurred in an OPEC member country; and 0 otherwise. $D_{autumn\ t}$, $D_{winter\ t}$ and $D_{spring\ t}$ are dummy variables taking the value 1 in the autumn, winter and spring seasons respectively; and 0 otherwise. Remaining variables are expressed as first difference between their natural log levels. TSIC: Transportation storage and insurance cost, OPEC: Organization of the Petroleum Exporting Countries

after 2007 into deep discounts. This dramatic change is attributed to the significant accumulation of domestic and Canadian crude stocks in the Cushing, in addition to limited pipeline capacity to move these crudes into the US Gulf Coast (Kao and Wan, 2012; Energy Intelligence, 2011; Fattouh, 2011; 2010). Distillate stocks show the most noticeable seasonality, which could be explained by the fact.

That the demand for heating oil, a middle distillate product, peaks during the winter season. TSIC shows high level of fluctuations specifically after 2002. This higher variability might be attributed to developments affecting the tankers market. Factors that have strengthened freight rates include rising prospects of a war on Iraq, extreme weather conditions in the US Gulf Coast, the Israel-Lebanon war in 2006 and rise in floating storage in 2009 (Energy Intelligence, 2011). On the other hand, the cut in OPEC production and arrival of new shipping capacity in 2007, in addition to the financial crisis have all weakened tankers rates during the 2000s (Energy Intelligence, 2011). Finally, Table 1 reports the unit roots results using the Augmented Dickey Fuller test; and assuming the equation contains an intercept and a trend. Lag selection is based on Schwartz Information Criterion (Schwartz, 1978). Findings show that logarithmic price differentials are stationary. Similarly, all of the explanatory variables, expressed in logarithmic differences, in equations (1) and (2) are stationary.

3. EMPIRICAL RESULTS, DISCUSSION AND ROBUSTNESS TESTS

3.1. WTI-Brent Spread, OPEC-Related Events and Control Variables

Table 3 shows the estimation results of model (1) and (2). The first noticeable observation relates to the statistically significant and negative β_1 coefficient in both regression equations. The results indicate that during periods in which unplanned production outages occur, the WTI-Brent spread narrows. This may not necessarily suggest that the two benchmarks move in the opposite direction during such episodes. Omar et al., (2013), for example, document economically and statistically significant positive abnormal returns for WTI during violent international conflicts. The results from model (1) and (2) may instead suggest that Brent is more responsive to these events than WTI. This finding may be unsurprising for a number of reasons.

As discussed earlier, Brent is waterborne crude that is transported to the major refining centers in Europe and the US (Fattouh, 2011; EIA, 1996). This is in a stark contrast to WTI that is landlocked and exposed to infrastructural bottlenecks. Therefore, in times of unmet international demand arising from OPEC outages, Brent would be expected to appreciate in value more radically. Additionally, in the case of outages in the production of competing crudes in the Atlantic basin, Brent price may rise to reflect the shortage and higher demand for it. Nigeria, whose crudes are exported to the US and other markets, witnessed major unplanned outages during the sample period.

In February of 2003 and 2006 Nigeria was forced to shut 37% and 20% of oil production respectively due to intensified fighting in the Niger Delta. Libya is an additional example. The country lost 1.6 million bbl/day of its production during the few months following the February 2011 revolution (Darbouche and Fattouh, 2011). The loss of the high quality Libyan crudes exerted an upward pressure on the similar quality grades of oil in the Atlantic basin in order to attract more of these crudes into Europe (Darbouche and

Figure 1: Fluctuations of crude oil spreads and control variables, (a) West Texas Intermediate-Brent free on board (FOB) (Spread in US dollar), (b) Light Louisiana sweet-Brent FOB (Spread in US dollar), (c) US industrial production, (d) US crude oil stocks excl. SPR (million barrels [mbbls]), (e) motor gasoline stocks (mbbls), (f) distillate stocks (mbbls), (g) residual fuel stocks (mbbls), (h) transportation storage and insurance cost ($ per Barrel), The diagrams below plot the crude oil spreads and control variables used in this study starting from May 1987 to December 2012. WTI-Brent and LLS-Brent are US dollar per barrel price differential. US industrial production index is seasonally adjusted (2007 = 100). Stocks of crude oil (excluding SPRs), gasoline, distillates and residual fuel are all in millions of barrels. TSIC is in US dollar per barrel.

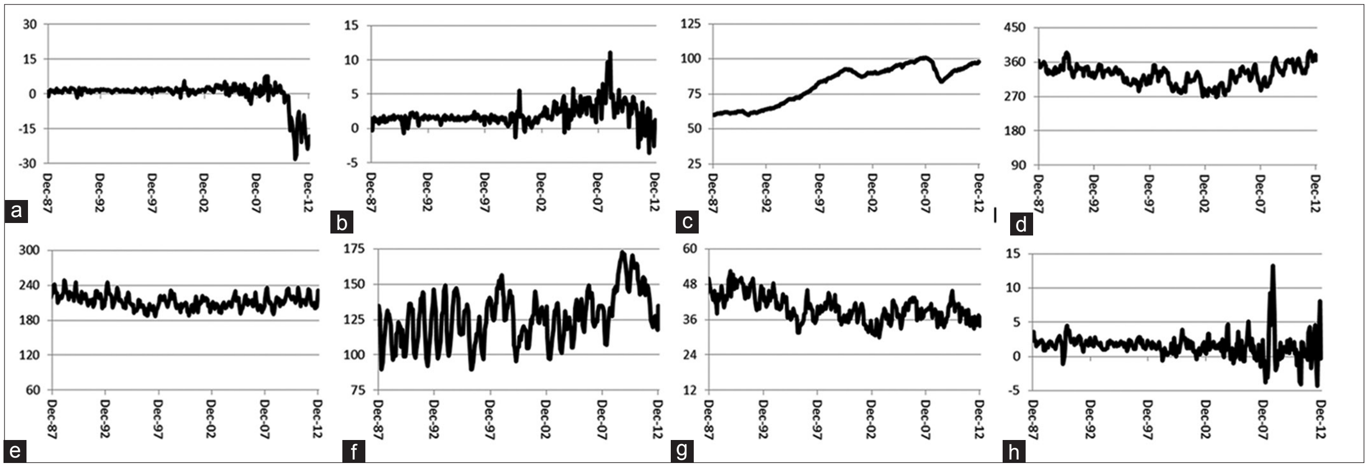

Table 3: WTI-Brent

Regression estimates for events of OPEC unplanned production outages			
Model (1) regression estimates		**Model (2) regression estimates**	
Constant	−0.0044 (0.0057)	Constant	−0.0006 (0.0072)
$D_{\text{Outages t}}$	−0.0141*** (0.0049)	$D_{\text{Outages t}}$	−0.0155*** (0.0048)
$D_{\text{Autumn t}}$	0.0060 (0.0055)	$D_{\text{Autumn t}}$	0.0003 (0.0073)
$D_{\text{Winter t}}$	0.0079 (0.0062)	$D_{\text{Winter t}}$	0.0101 (0.0105)
$D_{\text{Spring t}}$	0.0139** (0.0056)	$D_{\text{Spring t}}$	0.0064 (0.0065)
$USIP_{t-1}$	−0.0926 (0.4245)	$Stocks_{\text{Gasoline t}}$	−0.0903 (0.0780)
$Stocks_{\text{Crude t}}$	−0.1988** (0.0836)	$Stocks_{\text{Distillates t}}$	0.0032 (0.0490)
$TSIC_{t-1}$	0.1815*** (0.0466)	$Stocks_{\text{Residual t}}$	0.1275*** (0.0455)
$Sp_{WTI_{t-1}-Brent_{t-1}}$	0.7254*** (0.0766)	$TSIC_{t-1}$	0.1803*** (0.0454)
		$Sp_{WTI_{t-1}-Brent_{t-1}}$	0.7090*** (0.0787)
R^2	0.6942	R^2	0.6978
F-stat regression	84.5689	*F*-stat regression	76.1862
P value	0.0000	*P* value	0.0000

This table presents estimation results for the regression equation (1) and (2). Under model (1) the monthly natural log difference between prices of WTI and Brent is modeled as a function of OPEC-related production disruptions, seasonal dummies, first difference in the natural log levels of US industrial production with 1 month lag, natural logarithmic change in crude stocks excluding SPR, TSIC with 1 month lag; and 1 month lagged price differential. Model (2) replaces both crude stocks and US Industrial production in (1) with natural logarithmic changes in each of gasoline, distillate and residual stocks. The $D_{\text{Outages t}}$ takes the value of 1 in a 3 months event window centered on the month in which event occurred; and 0 otherwise. The table also reports the R^2, the corresponding *F*-statistic for the test of overall significance of the regression with the corresponding *P* value. Parameter standard errors are given in the parentheses. ***,**,*statistical significance at 1%, 5% and 10% level, respectively. TSIC: Transportation storage and insurance cost, WTI: West Texas Intermediate, OPEC: Organization of the Petroleum Exporting Countries

Table 4: LLS-Brent

Regression estimates for events of OPEC unplanned production outages			
Model (1) regression estimates		**Model (2) regression estimates**	
Constant	0.0223 (0.0041)	Constant	0.0192 (0.0060)
$D_{\text{Outages t}}$	0.0072** (0.0034)	$D_{\text{Outages t}}$	−0.0066** (0.0033)
$D_{\text{Autumn t}}$	0.0055 (0.0037)	$D_{\text{Autumn t}}$	0.0075 (0.0062)
$D_{\text{Winter t}}$	0.0041 (0.0053)	$D_{\text{Winter t}}$	0.0132 (0.0095)
$D_{\text{Spring t}}$	0.0074* (0.0038)	$D_{\text{Spring t}}$	0.0086 (0.0053)
$USIP_{t-1}$	−0.2014 (0.4037)	$Stocks_{\text{Gasoline t}}$	−0.1010* (0.0595)
$Stocks_{\text{Crude t}}$	−0.0464 (0.0512)	$Stocks_{\text{Distillates t}}$	0.0543 (0.0469)
$TSIC_{t-1}$	0.2038*** (0.0379)	$Stocks_{\text{Residual t}}$	0.0588* (0.0323)
$Sp_{LLS_{t-1}-Brent_{t-1}}$	0.3896*** (0.0699)	$TSIC_{t-1}$	0.2059*** (0.0351)
		$Sp_{LLS_{t-1}-Brent_{t-1}}$	0.3798*** (0.0720)
R^2	0.4040	R^2	0.4181
F-stat regression	25.2481	*F*-stat regression	23.7084
P value	0.0000	*P* value	0.0000

This table presents estimation results for the regression equation (1) and (2). Under model (1) the monthly natural log difference between prices of LLS and Brent is modeled as a function of OPEC-related production disruptions, seasonal dummies, first difference in the natural log levels of US industrial production with 1 month lag, natural logarithmic change in crude stocks excluding SPR, TSIC with 1 month lag; and 1 month lagged price differential. Model (2) replaces both crude stocks and US industrial production in (1) with the natural logarithmic changes in each of gasoline, distillate and residual stocks. The $D_{\text{Outages t}}$ takes the value of 1 in a 3 months event window centered on month in which event occurred; and 0 otherwise. The table also reports the R^2, the corresponding *F* statistic for the test of overall significance of the regression with the corresponding *P* value. Parameter standard errors are given in the parentheses. ***,**,*Statistical significance at 1%, 5% and 10% level, respectively. LLS: Light Louisiana sweet, TSIC: Transportation storage and insurance cost, OPEC: Organization of the Petroleum Exporting Countries

Fattouh, 2011). Thus, one would reasonably expect that such events would result in higher demand for alternative waterborne crudes like Brent, which happens to be supplied from a secure source.

The rise in demand for seaborne crudes from secure sources could be driven by precautionary reasons as pointed out by Terzian (1985. p. 260; cited in Kilian and Murphy, 2013) on the Iranian revolution and subsequent production disruption: "everybody was anxious to hang on to as much of their own oil as possible, until the situation had become clear. The shortage was purely psychological, or "precautionary" as one dealer put it." Furthermore, demand for oil could increase on speculative basis.

Kilian and Murphy (2013) show that there has been significant increase in the fossil fuel inventories prior to the 1990 invasion of Kuwait. They attribute the rise in stocks to either traders responding to the rising tension in the Middle East, or informed players acting in anticipation of that event. In a similar vein, Roekchamnong et al., (2014) demonstrate how the heightening in uncertainty could lead to a rise in stockpiles of petroleum products by businesses. The rise in demand, whether precautionary or speculative, due to events of disruptions or rising political uncertainty, is reasonably expected to favor waterborne over landlocked crudes; especially when such oil is produced from a secure source as is the case with Brent.

The results in Table 3 also show a statistically significant widening in the spread between WTI and Brent during spring relative to the summer season. This finding could be better understood in light of the relative importance of gasoline in the US. The transportation sector consumes 67% of the US petroleum use (Davis et al., 2013. p. 1). Gasoline is the fuel of choice and the demand for it accounts for 51% of total US demand for petroleum products (API, 2011. p. 30). The inadequate upgrading capacity for the poorer quality grades of oil and the tightest quality specifications for gasoline during summer are factors setting upward pressure on the prices of the higher quality crudes (Energy Intelligence, 2011; EIA, 1996). The relative increase in prices is pronounced for the higher quality domestic crudes such as WTI during the run-up to the summer driving season, which starts in late May (EIA, 1996).

Additionally, Table 3 shows a statistically significant and negative relationship between crude oil stocks and the price differential. This finding demonstrates the importance of stocks in acting as a cushion by supplying the marginal barrel (Kaufmann et al., 2008). Moreover, the negative relationship between the spread and US crude stocks may point to the vulnerability of WTI to infrastructural bottlenecks (Kao and Wan, 2012; Energy Intelligence, 2011; Fattouh, 2011; 2010). Kao and Wan (2012) further demonstrate that during periods of contango, the ability of WTI to process and reflect relevant news deteriorates.

The estimations in Table 3 attest to the role of transportation, storage and insurance cost in the relationship between the two benchmarks. The statistically significant and positive regression coefficient suggests that as cost increases, the spread widens indicating that Brent becomes less attractive for US refiners. This finding concurs with evidence that points to the significant role of transportation costs in the pricing relationships among crudes in various regions (Alizadeh and Nomikos, 2004; EIA, 1996; Weiner, 1991). A further interesting finding in Table 3 pertains to the relationship between the price differential and its lagged value. The statistically significant and positive regression coefficient in regression equation (1) suggests a persistent relationship between current and past price differentials. The persistence in the spread may reflect the consistency in freight rates or the quality of these crudes.

The second column of Table 3 reports estimation results of regression equation (2). In addition to confirming the results of model (1), the findings point at the role of residual fuel stocks. The increase in residual fuel stocks may indicate a higher level of utilization of the simple refining capacity at the time when the conversion and deep conversion units are fully utilized. The rise in the utilization of simple refining capacity may alternatively occur when a significant portion of the complex capacity is offline due, for example, to extreme weather conditions in the U.S. Gulf Coast.

A simple refinery (hydroskimming or topping) cannot alter the natural yield of products obtained from crude oil (International Council on Clean Transportation, 2011; Quarls et al., 2006; EIA, 1996). Thus, these simple refineries opt to procure oil that has high natural yield of light products, which subsequently sets an upward pressure on the prices of light and sweet crudes. Additionally, heavier crudes would suffer further discounts to induce demand from simple refineries. The combined effect would result in an increase in the stocks of residual fuel, and rise in the prices of light and sweet oil that might be more pronounced for domestic US crudes than foreign oil (EIA, 1996; Quarls et al., 2006).

In summary, the findings suggest that periods of unplanned outages in upstream production in OPEC give rise to a tightening price differential between WTI and Brent. This finding may not be surprising. Unlike the waterborne Brent, WTI is landlocked and can be heavily influenced by internal infrastructural issues that are unrelated to events in the international market for the fossil fuel. Additionally, the findings provide additional supporting evidence for the role of the stocks of crude oil and petroleum products in influencing pricing relationships among crudes. In particular, the positive relationship between residual fuel stocks and the price spread collaborates the theoretical framework in EIA (1996) and Quarls et al. (2006). Finally, the results point to a persistence in the price differential which might be explained on the basis of consistent crude qualities and freight rates.

3.2. Robustness Tests

The aim of this section is to examine the price differential between Brent and an alternative US domestic light and sweet crude that does not suffer from similar logistical problems as those experienced by WTI. LLS is the de facto light and sweet crude oil benchmark in the US Gulf Coast (Argus, 2012; Energy Intelligence, 2011). In addition to its high quality, LLS is praised for the close proximity to the Gulf Coast region. This region hosts 35% of the total number of refineries in the US; and holds 48% of total refining capacity in the country (Fattouh, 2011; Energy Intelligence, 2011; Andrews et al., 2010). Therefore, LLS is not exposed to the logistical problems faced by WTI. The robustness exercise involves replacing the WTI-Brent differential with the natural log price spread between LLS and Brent in regression equation (1) and (2). Estimation results from both equations are reported in Table 4.

The first observation to note in Table 4 pertains to the statistically significant and negative regression coefficient associated with the dummy of OPEC outages. This finding further supports the results from the previous analysis. This further attests to the prominent role of Brent as a global benchmark for waterborne crudes. Results in Table 4 also reveal LLS-Brent widens during the spring season compared to summer which affirms the higher US seasonal demand for the domestic light and sweet crudes. The cost of transportation, storage, and insurance has also a statistically significant and positive relationship with the price differential. Interestingly, the LLS-Brent spread shows similar persistence behavior over time. Table 4 reports additional interesting findings on the relationships between LLS-Brent differential and stocks of petroleum products. Changes in gasoline stocks are found to have a statistically negative effect on the LLS-Brent spread.

The significant Gulf Coast's share of total US refining capacity suggests that LLS would be more responsive to the build-up of gasoline stocks than WTI. Table 4 also documents a statistically significant and positive relationship between the differential and changes in residual fuel stocks. This affirms the role of residual fuel as a barometer for price relationships specially that LLS is the de facto benchmark in the US Gulf Coast. To put this into context, 87% of the 8.9 million bbl/d of refining capacity in the Gulf Coast is highly complex (API, 2011. p. 21).

As a further robustness test, I control for both the period of infrastructural bottlenecks in and around the Cushing, and the potential explanatory power of two different sets of events. The first is a sample 22 OPEC-related political conflicts not coinciding with disruptions. The second includes 104 monthly intervals in which hurricanes occurred in the Atlantic basin.[9] Therefore:

$$Sp_{\mathrm{WTI_t-Brent_t}} = C + \beta_1 D_{\text{Outages t}} + \beta_2 D_{\text{Conflicts t}} + \beta_3 D_{\text{Landlocked t}} + \beta_4 D_{\text{Hurricanes t}} + \beta_5 TSIC_{t-1} + \beta_6 Sp_{\mathrm{WTI_{t-1}-Brent_{t-1}}} + \varepsilon_t \quad (3)$$

Where the error term ε_t is assumed to be independently and identically normally distributed with mean 0 and variance equal to σ^2. $D_{\text{Conflicts t}}$ is a dummy variable which takes the value 1 if it falls in a 3 months event window in which an OPEC-related conflict not coinciding with a disruption occurred; and 0 otherwise. $D_{\text{Landlocked t}}$ is a dummy which takes that value 1 after February 2007, and 0 otherwise. $D_{\text{Hurricanes t}}$ is a dummy taking the value 1 for each month in which at least one hurricane occurred; and 0 otherwise. All the remaining variables are identical to those in model (1) and (2).

The construction of $D_{\text{Landlocked t}}$ follows Büyükşahin et al., (2013). They identify the period after February 2007 as that witnessing storage constraints in the Cushing due to increased US and Canadian production. Additionally that period experienced transportation bottlenecks which hindered the movement of crudes from the Cushing to the US Gulf Coast. The WTI-Brent price differential is replaced with LLS-Brent spread in equation (3) as an additional robustness check. Table 5 reports these regression estimates.

The results in Table 5 confirm the previous findings. This result is maintained even after accounting for the period of infrastructural bottlenecks, other OPEC-related conflicts and extreme weather conditions. A noticeable finding in Table 5 relates to the fluctuations of both price spreads after February 2007 as captured by the regression coefficient β_3 in model (3). While the WTI-Brent spread shows a statistically significant narrowing during the period of bottlenecks, the LLS-Brent differential exhibits insignificant fluctuation throughout that same time frame. This finding emphasized the landlocked nature of WTI; and highlights LLS's close proximity to the US major refining center.

9 According to the National Hurricane Center, the Atlantic basin includes the Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico. The Tropical Cyclone Report for each hurricane in each year since 1958 is available on http://www.nhc.noaa.gov.

Table 5: WTI-Brent and LLS-Brent, outages, conflicts, infrastructure and hurricanes

Model (3) regression estimates			
$Sp_{\mathrm{WTI_t-Brent_t}}$		$Sp_{\mathrm{LLS_t-Brent_t}}$	
Constant	0.0155 (0.0048)	Constant	0.0282 (0.0061)
$D_{\text{Outages t}}$	−0.0112** (0.0052)	$D_{\text{Outages t}}$	−0.0072** (0.0037)
$D_{\text{Conflicts}}$	−0.0055 (0.0042)	$D_{\text{Conflicts t}}$	−0.0016 (0.0035)
$D_{\text{Landlocked t}}$	−0.0235*** (0.0087)	$D_{\text{Landlocked t}}$	−0.0016 (0.0089)
$D_{\text{Hurricanes t}}$	−0.0045 (0.0039)	$D_{\text{Hurricanes t}}$	−0.0015 (0.0026)
$TSIC_{t-1}$	0.1312*** (0.0501)	$TSIC_{t-1}$	0.1944*** (0.0459)
$Sp_{\mathrm{WTI_{t-1}-Brent_{t-1}}}$	0.6603*** (0.0783)	$Sp_{\mathrm{LLS_{t-1}-Brent_{t-1}}}$	0.3871*** (0.0780)
R^2	0.6980	R^2	0.3990
F-stat regression	115.5671	F-stat regression	33.2001
P value	0.0000	P value	0.0000

This table presents estimation results for the regression equation (3). Under model (3) the monthly natural log difference between prices of WTI and Brent and LLS and Brent is each modeled as a function of OPEC-related production disruptions, OPEC-related conflicts not coinciding with disruptions, the period of infrastructural bottlenecks, extreme weather conditions, TSIC with 1 month lag; and one month lagged respective price differential. The $D_{\text{Outages t}}$ takes the value 1 in a 3 months event window centered on month in which event occurred; and 0 otherwise. $D_{\text{Conflicts t}}$ takes the value 1 in a 3 months event window centered on the month in which a conflict in OPEC occurred; and 0 otherwise. $D_{\text{Landlocked t}}$ takes the value 1 from March 2007 to December 2012; and 0 otherwise. $D_{\text{Hurricanes t}}$ takes the value 1 for months in which at least one hurricane occurred; and 0 otherwise. The table also reports the R^2, the corresponding F-statistic for the test of overall significance of the regression with the corresponding P value. Parameter standard errors are given in the parentheses. ***,**,*Statistical significance at 1%, 5% and 10% level, respectively. TSIC: Transportation storage and insurance cost, LLS: Light Louisiana sweet, WTI: West Texas Intermediate, OPEC: Organization of the Petroleum Exporting Countries

Overall, the findings from the robustness testing confirm the negative effect of unplanned disruptions in OPEC on the price differential between Brent and WTI. This tightening is robust even after accounting for the period of significant infrastructural constraints, extreme weather conditions, and disruption-free political conflicts. Furthermore, the findings can be generalized to the spread between Brent and LLS. The insensitivity exhibited by LLS-Brent to the cushing-related bottlenecks highlights the importance of both maritime transportation and crude's location. Finally, the absence of significant fluctuations in price spreads during disruption-free conflicts suggests the ability of market participants to effectively assess potential effects by political developments on upstream production.

4. CONCLUSION

The paper examined the behavior of the price differential between WTI and Brent during periods of supply disruptions. Using the Bloomberg's oil, natural gas field outages service, a sample is constructed consisting of 50 events of unplanned oil production outages in OPEC from 1987 to December 2012.

By specifying three linear models, and incorporating a number of explanatory variables, I demonstrated that periods supply disruptions give rise to a tightening spread between the two global benchmarks. This finding suggests that prices of Brent strengthen relative to those of the US counterpart during such episodes. This finding is robust when examining the spread between Brent and LLS; the de facto benchmark of light and sweet crudes in the US Gulf Coast.

During periods of production outages, demand for waterborne crudes from secure sources would rise to cover the shortage (Darbouche and Fattouh, 2011). Moreover, the increase in demand could be precautionary in nature or driven by speculative reasons prior to or during rising political tensions (Kilian and Murphy, 2013). The characteristics of Brent suggest that its price could be more responsive than that of WTI to events and developments concerning the security of crude oil supplies in the world. In contrast to Brent, WTI is a landlocked domestic crude, and its exposure to infrastructural bottlenecks have resulted in disconnecting its prices from those of other international crudes (Kao and Wan, 2012; Fattouh, 2011; 2010; Energy Intelligence, 2011). Therefore, the findings of this paper affirm the prominent role of Brent as a benchmark in the pricing of oil particularly in the Atlantic basin.

The paper further showed the importance of crude oil, gasoline, and residual fuel stocks. These stockpiles represent a barometer for the state of balance in petroleum markets and act as marginal sources of supply. Consequently, the patterns underlying their build-ups or draw-downs could be insightful for understanding price differentials. Moreover, the costs associated with transporting, storing, and insuring shipments of the fossil fuel were found to have a significant positive effect on the price differential.

These findings have a number of practical implications. The presence of vibrant futures exchanges opens the door for participants to use such derivative instruments for hedging and speculative purposes. The ICE provides market participants with the opportunity to trade the spread between Brent and WTI (ICE, 2014). The ICE also offers futures contracts on the LLS, which would suggest the potential for customized price differential trading.

Similarly, traders have the opportunity to trade the WTI-Brent spread through a variety of financial instruments provided by the CME group. Among these financial products is the WTI-Brent Financial futures contract specs which is financially settled and can be traded on open outcry or electronically (CME Group, 2009a). CME also offers electronic trading in the WTI-Brent crude oil spread call and put options with the WTI-Brent (ICE) Bullet Swap contract underlying these options (CME Group, 2009b). The use of these instruments would prove beneficial for oil producers, refiners, trading houses, and speculators.

The presence of a positive relationship between price differentials and logistical costs points to the importance of hedging this further risk exposure. Over-the-counter derivative instruments, such as forward freight agreements (FFRs), could be used to hedge the risk of future fluctuations in shipping rates. The popularity of FFRs has grown from 30 trades in 1997 to 500 in 2002; and in 2011, they accounted for 30% of physical trades in the tankers market (Energy Intelligence, 2011. p. 66).

Finally, the events that this paper examined could be challenging to anticipate in advance, which may suggest the need to a continuous exposure to the WTI-Brent spread. This implication is similar in spirit to that proposed by Omar et al., (2013). They argue that investment positions in oil should be a stable feature of a well-diversified portfolio because the "dynamics of the oil price may be understood only with the benefit of hindsight" (Omar et al., 2013. p. 30).

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