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The impact of crude oil prices on stock prices of oil firms: Should upstream-downstream dichotomy in supply chain be ignored?

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Abstract

In this paper, we query whether stock prices of non-integrated firms in upstream and downstream sectors of global oil supply chain respond similarly to changes in oil prices. This enquiry relates to "homogenous expectation" assumption among investors and fund managers pertaining to returns and variances of assets of specialized firms operating in upstream and downstream sectors of the supply chain. Using theoretical framework underpinned by the arbitrage pricing theory in conjunction with heterogeneous panel ARDL regression models, we find that stock prices of upstream and downstream firms move in contrasting directions in response to changes in benchmark crude oil prices in the long-run. Specifically, we show that stock prices of upstream sector firms increased in response to increase in oil prices, while the reverse holds for stock prices of downstream firms. In the short run, returns on stock of firms in both sectors increase following increase in oil prices; but downstream firms stock returns decreased in response to negative oil price shocks. Findings further show that both sectors respond differently to episodic changes in market conditions which emanated from the global financial crisis. However, upstream firms show stronger response to changing market conditions than their downstream counterparts.

JEL Codes: C23, F41, G11, G12, Q43

Keywords: stock price, crude oil price, price transmission, portfolio management

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1.0 Introduction

In spite of global and national efforts to reduce reliance of energy from oil and other fossil fuel sources to greener and sustainable sources in the last decades, crude oil remains a linchpin in modern industrial economies. Consequently, a plethora of literature has examined the nexus between oil price and macroeconomic variables (Hamilton, 1993, 1996; Ewing and Thompson, 2007; Bodenstein, 2012, Killian and Vigfusson, 2013; Naser, 2016, Killian and Vigfusson, 2017), oil and equity markets (Arouri and Rault, 2010; Sadorsky, 2014; Salisu and Oloko, 2015; Bondia, 2016; Reboredo, 2017), oil and bond market (Ciner, 2013; Kang, 2014), food markets (Gin, 2001; Alghalith, 2010, Lucotte, 2016; Kara, 2017), and wider commodity markets (Baffes, 2007, Wang, et al, 2014).

A common theme in the literature, especially studies on equity markets, is the tendency to treat the oil and gas sector as a monolithic and uniform supply chain. This approach ignores niches of operational specialty in the chain as well as differing capital structure, leverage and risk profiles of non- (vertically) integrated firms in upstream and downstream sectors of the supply chain. For example capital structure, input costs and physical equipment utilized by firms in drilling (upstream sector) are likely to be different and more 'sunk' than firms in retail and marketing of oil products (downstream). Moreover, capital specificity within sector means that specialized edging tools used for oil exploration and drilling may have little or no alternative uses to the retail and marketing.

The private sector involvement in global oil and gas supply has historically been dominated by large vertically integrated oil firms (especially the supermajors) [1] and

[1] Often referred to as 'big oil' consisting of large integrated publically owned oil firms including ExxonMobil, British Petroleum, Royal Dutch Shell, Chevron Corporation, ConocoPhillips, Total SA and Eni SpA.

their nationalized oil counterparts[2] whose activities span the entire supply chain including drilling, exploration and production, storage and transportation and retail and marketing of oil products. These firms undertake diverse range of operations in many countries on different continents and are highly visible to investors. However, their smaller non-integrated counterparts, which they sub-contract to, tend to compartmentalize their activities in the supply chain. Some firms operate in the upstream sector of the supply chain including exploration and production and drilling while others are more downstream in pipelines, refining and marketing. Unlike the supermajors and nationalized oil firms, non-integrated oil firms are often less visible compared to their integrated firms, and have consequently received very limited attention in the literature. Therefore, we intend to fill the gap in the literature on the response of asset prices of non-integrated firms in upstream and downstream sectors of the supply chain to oil prices as well as other macroeconomic shocks in this paper.

The questions we intend to answer in this paper are: i) Does crude oil price have differential impact on stock prices of firms in upstream and downstream sectors of oil and gas supply? ii) Do stock prices of firms in the same sector respond uniformly to stock price in crude oil prices? And finally, iii) did the global financial crisis affect the response of upstream and downstream firms stock prices to changes in oil prices? These questions are vital to understanding debates relating to "homogenous expectation" of returns and variances of stocks of firms operating in the oil supply chain (Bogue and Rolls, 1974, Levy and Levy, 1996). They are important to investors and portfolio managers seeking to diversity their portfolios, and for capital budgeting purposes.

We argue that changes in crude oil prices are likely to have differential impacts on stock prices and investment prospects of firms in upstream and downstream sectors of oil

[2] For example the so-called "new seven sisters" and many other state-controlled oil firms described Carola Hoyes article in Financial Times on March 12, 2007.

supply chain. In other words, the response of stock prices of firms in upstream and downstream segments to movements in oil prices may not be similar, and therefore investors should not assume homogenous expectations in relation to risk associated with firms in the two sectors.

The model employed in this study is motivated by the Arbitrage Pricing Theory and thus we are also able to capture the exposure of the stock returns of the non-integrated oil firms to foreign exchange risk, interest rate risk and macroeconomic risk. In any case, the magnitude of oil price volatility transmission may be tempered by some macro-financial variables such as those mentioned. Since we are dealing with two sectors, our econometric analyses follow the non-stationary heterogeneous panel framework which is suitable for large N and large T panels. Both the long-run and short-run responses of these two sectors to oil price volatility are evaluated. For the asymmetric version, we apply the Shin et al. (2014) approach to decompose the oil prices into positive and negative shocks (i.e. upward & downward swings in oil price). The implications of our empirical findings to investors as well as policy makers are well documented in the paper.

Following this section, we structure the rest of the paper as follows. The next section explains the theoretical framework and the econometric model for the oil price-stock nexus. Section 3 describes the data used for estimation and also renders some preliminary analyses. In Section 4, we present and discuss the regression results including diagnostics and robustness tests. Section 5 concludes the paper.

2.0 Theoretical Framework

The pricing of risky assets has dominated discussions in finance. The underlying intuition is that returns from financial assets come with risks and therefore investors and fund managers need information about the nature and sources of risks that may affect asset returns. This is particularly useful to investors when making investment decisions on possible portfolio diversification in the presence of risks. Several theories have been developed to offer explanations to the different plausible ways of pricing assets. Among these theories are the traditional Capital Asset Pricing Model (CAPM) (see Sharpe, 1964, 1970) and its variants such as the Conditional CAPM (see Jagannathan and Wang, 1996); the Intertemporal CAPM (see Merton, 1973, 1990); the Consumption-Based CAPM (see Breeden, 1979) and the International CAPM (see Stulz, 1981a, 1981b, 1995). Others include, but not limited to, Fama and French models [i.e. the three-Factor model (see Fama and French, 1993, 1995, 1996) and the five-factor model (see Fama and French, 2015, 2017)] and the Arbitrage Pricing Theory (APT) (see Ross, 1976). Each of these theories is evaluated using one of the two main methodologies described as the equilibrium approach and the arbitrage approach. For instance, the CAPM and its variants employ the equilibrium approach while the Fama and French models and the APT involve the arbitrage approach. The CAPM and its variants prominently rely on three assumptions: (1) that all agents have the homogeneous expectations about future returns; (2) that there is a linear relationship between the expected return and the relative risk of an asset and; (3) that the expected returns are explained only by a single variable.[3] In addition to the fact that the assumptions have been found to be unrealistic practically, more recent evidence have suggested that the CAPM cannot adequately explain the observed returns. For instance, including variables such as book-market ratios, market value of a company or price-earnings ratios as in the Fama and French model may render the beta in the CAPM insignificant (see Krause, 2001).

Owing to these shortcomings and other considerations, we favour the APT over other asset pricing models. Krause (2001) documents some of the advantages of using the

[3] Other restrictive assumptions of the traditional CAPM such as unconditional beliefs, exogenously given amount to invest and a single period investment horizon have been relaxed and taken into account in the Conditional CAPM, Consumption-Based CAPM and Intertemporal CAPM respectively.

APT to model stock returns over other asset pricing models. Unlike in the CAPM where all risks are aggregated into a single risk factor (i.e. the market risk), the APT allows for multiple risk factors including industry and country specific characteristics. This aggregation is useful for optimal or at least well diversified portfolios, but for the explanation of returns of individual assets this aggregation may be problematic (Krause, 2001). In essence, the APT provides a framework that captures the different sources of systematic risk by splitting this risk into its various components. While the Fama and French models also allow for up to five (firm-specific) risk factors, however extending the CAPM to include these factors only does not perform approximately well (see Krause, 2001). Also, Jagannathan and Wang (1996) find that by including other risk factors, different from those of Fama and French (1992, 1993), the performance can be increased significantly by using monthly frequency instead of annual. In addition, Danthine and Donaldson (2015) note that the SMB (the ‘‘size’’) and HML (the “value”) factors in the Fama and French (1992, 1993) in a way capture fundamental systematic macroeconomic risks including the business cycle usually measured with the rate of growth of the underlying economy’s GDP. In other words, the APT, if properly constructed can as well represent the components of the Fama and French models particularly the three-factor model. Thus, the APT which allows for both macroeconomic risks and industry specific characteristics is broader in scope and seems more straightforward and realistic than the equilibrium-based asset pricing models.

We are mindful of the fact that the APT is not explicit as to the specific quantitative factors underlying common stock returns. Thus, we complement our choice of risk factors with relevant theoretical discussions. We therefore provide the underlying theoretical motivation for each of these factor risks in subsequent sub-sections.

2.1 Stock returns and Oil price

The exposure of the non-integrated oil firms to oil price risk can be explained from the cash flow hypothesis by Jones and Kaul (1996) and the supply- and demand-side hypotheses by Kilian and Park (2007). The cash flow hypothesis assumes that oil price can affect stock price directly by impacting on future cash flows or indirectly through interest rate used to discount the future cash flows. Using the interest rate channel, higher oil prices may lead to overestimation of the expected inflation and thus higher nominal interest rates; and since discount rates are negatively related with stock prices, increases in interest rates depress stock prices (Rafailidis and Katrakilidis, 2014). In other words, in the spirit of the cash flow hypothesis, the relationship between oil price and stock returns is negative.

On the other hand, the demand- and supply-side hypotheses of Kilian and Park (2007) assume that the response of stock price to oil price changes can be either positive or negative depending on whether the changes in oil price are driven by demand- or supply-side shocks. For instance, the stock returns can respond negatively to oil price shocks if the shocks arise from the uncertainty about future crude oil supply shortfalls. However, the response will be positive if the shocks are driven by an unanticipated global expansion (see also Apergis and Miller, 2009). In addition to oil price, we also account for other macroeconomic variables that have been validated as risk factors for explaining stock returns. The prominent among these variables are GDP growth or growth of industrial production to measure the exposure of stocks to business cycle (see Humpe and Macmillan, 2007; Tsagkanos and Siriopoulos, 2015 for a review); exchange rate to measure exposure to foreign exchange risk (see Salisu, and Oloko, 2015; Tsen, 2016 for a review), inflation to measure macroeconomic uncertainty (see Tiwari et al., 2015 for a review) and interest rate spread to capture interest rate risk (see Papadamou et al., 2016 for a review). Like the oil price and stock returns nexus, we also justify the inclusion of other macroeconomic risks both theoretically and empirically as highlighted in subsequent sub-sections.

2.2 *Stock returns and inflation*

There are three hypotheses that seem to have emerged in relation to the stock returns-inflation nexus. These are the Fisherian hypothesis, Hedge hypothesis and the Deman hypothesis arising from the ''proxy effect". The first two hypotheses are discussed simultaneously as the validity of one implies the validity of the other. The Fisherian hypothesis assumes neutrality of real stock returns to rising inflation while the Hedge hypothesis assumes a positive relationship between nominal stock return and inflation. This indicates if the Fisherian hypothesis is valid, then the positive relationship between nominal stock returns and inflation is not in doubt. Thus, the difference in the hypothesis lies in the proxy for stock returns. In essence, in testing for the validity of Fisherian hypothesis, one is required to use the real stock return and the coefficient on inflation is not expected to be significant. However, in testing for the validity of the hedging property of inflation, the nominal stock return is used and the resulting coefficient on inflation is then examined to verify the hedging property of inflation. A positive and significant coefficient on inflation implies that the nominal stock return already subsumes the rising inflation and the risk (inflation) adjusted stock return is expected to be inflation neutral. These two hypotheses are premised on the fact that investors in the stock market are fully compensated for upward movements in the general price level through corresponding increases in the nominal stock market returns and thus the real returns remain independent and unaffected (see Tiwari et al., 2015).

However, a number of studies have rejected the Fisherian hypothesis and reported a negative relationship between stock return and inflation (see for example, Linter, 1975;

Fama, 1981; Geske and Richard, 1983 and Asprem, 1989) thereby rejecting the Fisherian hypothesis and by implication renders the hedge hypothesis invalid. These conflicting findings may be as a result of the measure for inflation. For instance, Chatrath et al. (1996) note that the real stock returns serve as perfect hedge (as in the case of Fisherian and Hedge hypotheses) if the expected component of the inflation is used while the unexpected component of inflation shows a negative relationship between real stock return and inflation (see also Tiwari et al., 2015). The argument in support of this negative relationship stems from the Demand hypothesis which establishes a negative relationship between demand and price. For instance, an unexpected rise in inflation affects the purchasing power of the currency in question which consequently causes the demand for goods to decline. With the decline in demand, revenues and profits will also decline and by extension the overall economy slows down including the stock market. This notion is also described as "proxy effect" by Fama (1981) since the negative relation between stock return and inflation is inferred from the negative effect of the latter on real economic activity.

2.3 *Stock returns and real economic activity*

The theoretical relationship between stock returns and the real economic activity is often anchored on the demand-side shock which suggests a positive relationship between stock returns and growth in industrial production (a prominent proxy often used in the literature to capture real economic activity). For instance, if a positive productivity shock (that is coming from the respective positive demand shock) hits the industrial sector, the increase in production leads to higher revenues and profits which causes an increase in dividends and, therefore, stock prices (Tsagkanos and Siriopoulos, 2015).

2.4 *Stock returns and interest rate*

The relationship between stock returns and interest rate has been explained from two perspectives – the wealth effect and the substitution effect. These two effects are consistent with the postulations by Friedman (1988) regarding the nature of relationship between the money market and the stock market. The wealth effect assumes a positive relationship between stock prices and money – that is, a fall in money demand (possibly as a result of a higher rate of return on treasury bonds/bill) reduces the demand for stocks. As a consequence, a negative relationship is expected between interest rate and stock returns. This negative association can also be explained from the perspective of the cashflow hypothesis which establishes that a higher nominal interest rate (possibly as a result of monetary policy tightening) will depress stock prices and since the former is used to discount the future cashflows.

For the substitution effect, a negative relationship between the two money and stock price is assumed to be negative. This is underscored by the fact that a fall in the return on treasury bill/bond will lead to an increase in the demand for stocks which consequently leads to a rise in the stock returns.

2.5 *Stock returns and exchange rate*

The only prominent theoretical model often used to explain how exchange rate impacts on the behavior of stock returns is the Flow model proposed by the Dornbusch and Fischer (1980). This model assumes a positive relationship between stock returns and exchange rate. For example, if exchange rate of a home country depreciates, it will enhance its trade competitiveness which leads to an increase in its production, profits, and by extension stock returns, where stock return is defined as the net present value of the future cash flow of a company (Salisu and Oloko, 2015). In other words, depreciation of real exchange rate will increase real stock price whilst appreciation of real exchange rate will decrease real stock price (see Dornbusch and Fischer, 1980; Pan et al., 2007; Ülkü and Demirci, 2012; Tsen, 2016).

It is however important to point out that findings in the literature differ in terms of how these macroeconomic variables have been able to explain the behavior of stock returns. However, we argue that the nature of the stocks or portfolio under consideration may affect how the stock prices respond to macroeconomic factors. We are of the opinion that oil–related stocks are more likely to be driven by macroeconomic factors as long as energy continues to serve as a major input to production process.

3.0 The Model and Estimation Procedure

As previously noted, our empirical model hinges on the APT which allows us to capture different risk factors including oil price changes in the stock model. More specifically, we add other relevant macroeconomic variables that have been theoretically and empirically validated as important drivers of stock market behaviour. This is important in order to produce robust estimates about the possible spillover transmission between oil price and the stock prices of non-integrated oil firms.

A typical representation for the APT assumes that investors believe that the $n\times1$ vector, r, of the single-period random returns on capital assets satisfies the factor model given below (see Huberman and Wang, 2005):

$$r = \alpha + \beta f + \varepsilon, \tag{1}$$

where α is an $n\times1$ vector of the constants; f is a $k\times1$ vector of random variables (factors); β is an $n\times k$ matrix of beta or factor loading and ε is an $n\times1$ vector of disturbances. It is assumed that the $E(f)=0$ and $E(\varepsilon)=0$ where 0 denotes the vector of zeros with the corresponding dimension for f and ε. As a consequence, the $E(r)=\alpha$. These assumptions are realizable if the factors are correctly specified. For instance, if we assume that a series, say x_t, exhibits unit root (which is a prominent feature of most economic series including those that are used in this study), then, $E(\Delta x_t) = 0$,[4] which explains why macroeconomic variables in the APT model are expressed in either difference form or in the form of rate of change. In other words, specifying the macroeconomic variables this way ensures the validity of the APT assumptions.

Thus, in this study, we consider the autoregressive distributed lag model (ARDL) which allows for the estimation of both long run and short run response of non-integrated oil firms stock prices to oil price shocks. Since the firms are grouped into Upstream and Downstream sectors, we expressed the ARDL in panel form. This version of panel regression hinges on the non-stationary heterogenous panel regression model. There are three interesting features of this panel econometric model which seem to align with the objectives of this paper as well as the underlying assumptions of the APT. First, the model allows for non-stationarity which is envisaged given the nature of the economic series being analyzed. In other words, the model is used where non-stationarity is a concern. Also, the assumption of non-stationarity for the underlying series helps us to validate the applicability of the APT as previously highlighted. We further argue that the investors in the Upstream and Downstream sectors may not exhibit homogenous expectations about their stock returns in the presence of oil price risk and therefore it becomes imperative to capture any inherent heterogeneity in the beta or factor loading. Finally, the model is suitable for large N and large T panels. Both the long-run and short-run responses of these two sectors to oil price volatility are evaluated. As previously noted, we also account for nonlinearity in oil price using the Shin et al. (2014) approach. This allows us to capture the response of stock prices to positive and negative changes in oil price.

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[4] Note that a series is assumed to exhibit unit root if x_t is given as $x_t = \rho x_{t-1} + \upsilon_t$ and $\rho = 1$ such that $x_t - x_{t-1} = \Delta x_t = \upsilon_t \sim \left(0, \sigma^2\right)$ and therefore $E(\Delta x_t) = 0$.

The panel ARDL model is expressed below:

$$\Delta s_{it} = \alpha_{0i} + \beta_{1i}s_{i,t-1} + \beta_{2i}p_{t-1} + \beta_{3i}e_{t-1} + \beta_{4i}y_{t-1} + \beta_{5i}i_{t-1}^{d} + \beta_{6i}\pi_{t-1} + \sum_{j=1}^{N1}\psi_{1ij}\Delta s_{i,t-j} + \sum_{j=0}^{N2}\psi_{2ij}\Delta p_{t-j} + \sum_{j=0}^{N3}\psi_{3ij}\Delta e_{t-j} + \sum_{j=0}^{N4}\psi_{4ij}\Delta y_{t-j} + \sum_{j=0}^{N5}\psi_{5ij}\Delta i_{t-j}^{d} + \sum_{j=0}^{N6}\psi_{6ij}\Delta \pi_{t-j} + \mu_i + \varepsilon_{it}$$

$$i = 1,\ 2,\ N; \qquad t = 1,\ 2, \ldots,\ T. \qquad (2)$$

where s_i is the log of stock price for each unit i; p denotes the log of oil price benchmark; e is the log of real effective exchange rate; y is the log of industrial production index; i^d is the term structure computed as the difference between the long-term US Treasury bonds measured at period *t* and the Treasury bill (short rate) in period *t-1* (see Danthine and Donaldson, 2015); π is the inflation rate measured by the log of consumer price index (and therefore, we restrict the inflation to the anticipated component); μ_i is the group-specific effect; *i* is the sampled units and *t* is the number of periods.[5] For each cross-section, the long run slope (elasticity) coefficients are respectively computed as $-\frac{\beta_{2i}}{\beta_{1i}}$, $-\frac{\beta_{3i}}{\beta_{1i}}$, $-\frac{\beta_{4i}}{\beta_{1i}}$, $-\frac{\beta_{5i}}{\beta_{1i}}$ and $-\frac{\beta_{6i}}{\beta_{1i}}$ for oil price, exchange rate, output, interest rate and inflation. This calculation is derived under the assumption that in the long run, $\Delta s = \Delta p = \Delta e = \Delta y = \Delta i^d = \Delta \pi = 0$. This is realizable if the model satisfies criteria for convergence which can be evaluated using the error correction representation for equation (2) (this is discussed subsequently). The corresponding short run estimates for the relevant variables are ψ_{2ij}, ψ_{3ij}, ψ_{4ij}, ψ_{5ij} and ψ_{6ij} in the same order.

[5] In addition to the theoretical justification for the included variables in the model, our choice is consistent with the most significant variables in the Chen et al. (1986) paper which explores the explanatory power of a wide class of factors before arriving with those captured in our model (see also Danthine and Donaldson, 2015).

Note that the variables are expressed in first difference form in the short run as conventionally required; this somewhat guarantees the realization of the restrictions on the APT. Similarly, the reparameterization of equation (2) through the error correction framework ensures that the restrictions are also not violated in the long run (see equation (3) below). Put differently, the model satisfies criteria for convergence and by implication confirms the assumptions of APT also in the long run if the coefficient on the error correction is negative, less than one in absolute term and statistically significant. Thus, eequation (2) is re-specified to include an error correction term as follows:

$$\Delta s_{it} = \lambda_i \upsilon_{i,t-1} + \sum_{j=1}^{N1} \psi_{1ij} \Delta s_{i,t-j} + \sum_{j=0}^{N2} \psi_{2ij} \Delta p_{t-j} + \sum_{j=0}^{N3} \psi_{3ij} \Delta e_{t-j} + \sum_{j=0}^{N4} \psi_{4ij} \Delta y_{t-j} + \sum_{j=0}^{N5} \psi_{5ij} \Delta i^d_{t-j} + \sum_{j=0}^{N6} \psi_{6ij} \Delta \pi_{t-j} + \mu_i + \varepsilon_{it} \qquad (3)$$

where $\upsilon_{i,t-1} = s_{i,t-1} - \phi_{0i} - \phi_{1i} p_{t-1} - \phi_{2i} e_{t-1} - \phi_{3i} y_{t-1} - \phi_{4i} i^d_{t-1} - \phi_{5i} \pi_{t-1}$ is the linear error correction term for each unit; the parameter λ_i is the error-correcting speed of adjustment term for each unit which is expected to satisfy the criteria earlier mentioned. The parameters ϕ_{0i}, ϕ_{1i}, ϕ_{2i}, ϕ_{3i}, ϕ_{4i} and ϕ_{5i} are computed as $-\frac{\alpha_i}{\beta_{1i}}$, $-\frac{\beta_{2i}}{\beta_{1i}}$, $-\frac{\beta_{3i}}{\beta_{1i}}$, $-\frac{\beta_{4i}}{\beta_{1i}}$, $-\frac{\beta_{5i}}{\beta_{1i}}$ and $-\frac{\beta_{6i}}{\beta_{1i}}$ respectively.

As part of our objectives, we also decompose oil price shock into positive and negative shocks using the Shin et al. (2014) approach. Note that in equations (2) and (3), there are no decompositions of oil price into positive and negative changes; hence, the impact of oil price shock under this situation is considered identical (i.e. symmetric). In the asymmetric case, we are able to evaluate whether it is important to account for asymmetries when dealing with oil price-stock nexus of non-integrated oil firm. This is particularly important in two ways. First, we are able to examine whether stock prices of both the Upstream and Downstream sectors are not linearly related to oil price or not. There are three possible cases in this regard: (i) symmetry in both sectors; (ii) asymmetry in both case and (iii) asymmetry in one and symmetry in the other. Secondly, in connection with these classifications as in the latter, we are able to offer some useful generalizations about the response of the Upstream and Downstream sectors of the non-integrated oil firms to oil price shocks. Nonetheless, we consider baseline regression involving the full sample which discards the separation of the sampled data into Upstream and Downstream sectors. This additional consideration helps to estimate the extent to which the estimates of the relationship between oil price and stock prices are over-estimated or under-estimated when we assume homogenous expectations. Thus, the asymmetric version of equation (2) is given as:

$$\Delta s_{it} = \alpha_{0i} + \beta_{1i} s_{i,t-1} + \beta_{2i}^{+} p_{t-1}^{+} + \beta_{2i}^{-} p_{t-1}^{-} + \beta_{3i} e_{t-1} + \beta_{4i} y_{t-1} + \beta_{5i} i_{t-1}^{d} + \beta_{6i} \pi_{t-1} + \sum_{j=1}^{N1} \psi_{1ij} \Delta s_{i,t-j}$$
$$+ \sum_{j=0}^{N2} (\psi_{2ij}^{+} \Delta p_{t-j}^{+} + \psi_{2ij}^{-} \Delta p_{t-j}^{-}) + \sum_{j=0}^{N3} \psi_{3ij} \Delta e_{t-j} + \sum_{j=0}^{N4} \psi_{4ij} \Delta y_{t-j} + \sum_{j=0}^{N5} \psi_{5ij} \Delta i_{t-j}^{d} + \sum_{j=0}^{N6} \psi_{6ij} \Delta \pi_{t-j} + \mu_i + \varepsilon_{it}$$

(4)

where p_t^{+} and p_t^{-} denote the positive and negative shocks respectively and they are computed as positive and negative partial sum decompositions of oil price changes as defined below (see Shin et al., 2014):

$$p_t^{+} = \sum_{k=1}^{t} \Delta p_{ik}^{+} = \sum_{k=1}^{t} \max(\Delta p_{ik}, 0) \quad (5)$$

$$p_t^{-} = \sum_{k=1}^{t} \Delta p_{ik}^{-} = \sum_{k=1}^{t} \min(\Delta p_{ik}, 0) \quad (6)$$

There is evidence of asymmetry, if the coefficients of p_t^{+} and p_t^{-} are statistically different from each other; otherwise their effect on stock returns is considered identical.

For the purpose of estimation, we consider both the Mean Group (MG) and Pooled Mean Group (PMG) estimators both of which are prominent estimators for nonstationary and heterogenous dynamic panels.[6] Consequently, we subject the results from these estimators to Hausman test. A non-rejection of the null hypothesis implies the adoption of the PMG estimator while the rejection indicates the adoption of the MG estimator (Blackburne and Frank, 2007; Salisu et al., 2017). In other words, the PMG estimator is the efficient estimator under the null while the MG estimator is the efficient estimator under the alternative hypothesis (Blackburne and Frank, 2007; Salisu et al., 2017).[7]

4.0 Data and Preliminary Analyses

Our data scope for the purpose of empirical analyses ranges from January 2000 to February 2017. For the non-integrated oil firms, we were able to collect data on the stock prices of 102 Upstream firms (15 for Drilling and 87 for Exploration and Production) and 114 Downstream firms (45 Storage & Transportation and 69 Retail and Marketing firms). Narayan and Bannigidadmath (2015) provide further justifications for selection of firms using a range of financial variable predictors.

In all, our data covers 216 non-integrated oil firms. For the oil price, we consider the spot prices of three prominent benchmark crudes namely West Texas Intermediate (WTI), Brent and Dubai Fateh. Essentially, we use Brent sport price for the main analyses while the other two global oil price proxies are used for robustness. Stock price data were sourced from Thomas Reuters while the oil price data were obtained from the US Energy Information Administration.

[6] The computational procedures for these estimators including relevant STATA codes are available in Blackburne and Frank (2007).

Or [7] All the regression results for both the MG and PMG estimators including relevant STATA codes used in this paper are available on request.

Before the main estimation, we offer some preliminary analyses such as descriptive statistics (mean and standard deviation) and panel unit root tests. Table 1 shows the descriptive statistics for the relevant variables in the model. A cursory look at the table reveals that the Upstream sector may have witnessed an upward trend in stock prices than the Downstream sector, on average, judging by their mean values. Also, the same pattern is observed for standard deviation. In other words, the Upstream sector tends to exhibit a higher volatility than their Downstream counterparts. This trend seems to attest to the norm in finance theory (on the basis of the CAPM), which assumes that the higher the risk, the higher the returns and vice versa. This norm is also upheld for the two components of each sector. For example, the Exploration and Production sub-sector of the Upstream records a higher mean value and a higher standard deviation than the Drilling sub-sector. Similarly, the Storage and Transportation sub-sector of the Downstream sector which records a higher mean value than the Retail and Marketing also exhibits a higher volatility. This suggests the possibility of Midstream sector consisting of firms in Drilling and Storage and Transportation which have similar average mean values, albeit standard deviations. However, this study focuses on broad Upstream versus Downstream sector bifurcations of the supply chain, and there corresponding sub-sectors. Thus, the distribution of the stock price data used for analyses in this paper seems to be consistent with theory. Similar conclusions seem to hold for oil prices; Bent has the highest mean and standard deviation values. In other words, Brent crude price has witnessed more variations than the WTI and Dubai-Fateh over the period under consideration. We also find that the variations in the other variables (output, exchange rate and interest rate spread) are minimal indicating that their movements have been fairly stable compared to the stock price and oil price.

Table 1: Descriptive statistics

Table 1A: Descriptive statistics for the stock prices of the Downstream & Upstream sectors

Statistics	Upstream	E&P	Drilling	Downstream	S&T	R&M

Mean	26.096	26.654	22.863	16.352	21.574	12.946
Std. Dev.	148.817	160.858	22.531	35.922	36.948	34.819
Observations	20706	17661	3045	23142	9135	14007

Note: The acronyms E&P, R&M and S&T denote Exploration and Production, Retail & Marketing and Storage & Transportation firms respectively.

Table 1B: Descriptive statistics for the oil prices of benchmark crudes and other variables

	p_t					
Statistics	**Brent**	**WTI**	**Dubai**	y_t	i_t^d	e_t
Mean	65.392	62.906	62.525	98.964	0.445	108.787
Std. Dev.	32.119	27.920	31.572	4.895	0.418	10.049
Observations	203	203	203	203	203	203

Note: p_t, y_t, i_t^d and e_t represent the oil price, output, interest rate spread and real effective exchange rate respectively.

As a precondition for the choice of empirical model involving large *N* and large *T* panels, we also conduct panel unit root test for all the variables in the model (see Table 2). We consider both the stationarity test (such as the Hadri, 2000 Lagrange Multiplier test) and the non-stationarity tests (such as the Im, Pesaran and Shin, 1997; Harris and Tzavalis, 1999; Breitung, 2000; and Levin, Lin and Chu, 2002 tests). The unit root test results for the stock prices are presented in Table 2A. We find that the stock prices of the Upstream including its components (Drilling and Exploration and Production) are integrated of order one [*I*(1)] regardless of the test type while the results are mixed for the Downstream sector as well as its sub-sectors. For example, the Harris-Tzavalis and the Im-Pesaran-Shin (IPS) unit-root tests indicate that the stock prices of the Downstream are *I*(0), all the other tests however suggest otherwise. The unit root test results for oil prices and other variables are presented in Table 2B. Like the upstream sector, the oil prices with the exception of WTI also exhibit *I*(0) irrespective of the test employed. However, all the other variables depict mixed order of integration. Since the underlying framework for estimation allows for the combination of both *I*(0) and *I*(1) (in so far the level of stationarity does not exceed *I*(1)), then, the mixed order of integration for some variables in the model is not expected to bias our estimates.

Table 2: Panel unit root tests

Table 2A: Panel unit root tests for stock prices

	Upstream	**Drilling**	**E&P**	**Downstream**	**R&M**	**S&T**
Null Hypothesis: unit root with common process						
LLC	-0.013^{b***}	-47.7322^{b***}	-0.015^{b***}	-0.012^{b***}	-83.4462^{b***}	-88.069 ^{b***}
Breitung t-stat.	-13.344 ^{b***}	-6.5401^{b***}	-13.483 ^{b***}	-8.3973^{b***}	-7.9020^{b***}	-1.9876^{a**}
Harris-Tzavalis	-0.105 ^{b***}	0.0618^{b***}	-0.117^{b***}	0.8774^{a***}	0.8499^{a***}	-0.0123^{b***}
Null Hypothesis: unit root with individual unit root process						
IPS (W Stat)	-0.013^{b***}	-46.374^{b***}	-0.013^{b***}	-1.6747^{a**}	-0.011^{b***}	-1.7049^{a**}
Null Hypothesis: no unit root with common unit root process						
Hadri Z-stat.	0.9117 ^{b}	-0.6312^{b}	1.133 ^{b}	-3.3557^{b}	-3.2884^{b}	0.5839^{b}

Note: *a* and *b denote* stationarity at level and at first difference respectively, while ***, **, * indicate statistical significance at 1%, 5% and 10% respectively. The LLC denotes Levin, Lin and Chu, 2002 test. All the stock price variables are expressed in natural logs.
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Table 2A: Panel unit root tests for oil prices and other variables

	p_t			y_t	i_t^d	e_t	π_t
	BRENT	**WTI**	**DUBAI**				
Null Hypothesis: unit root with common process							
LLC (t)*	-0.015^{b***}	-3.7516^{a***}	-0.014^{b***}	-14.400^{a***}	7.256^{a***}	-4.6903^{a***}	-16.431^{a***}
Breitung t-stat.	-4.319^{b***}	-4.483^{b***}	-4.010^{b***}	-1.7949^{a**}	-1.4163^{a*}	-2.5679^{b***}	-4.355^{b***}
Harris-Tzavalis (rho)	0.247^{b***}	0.299^{b***}	0.323^{b***}	0.247^{b***}	0.877^{a***}	0.341^{b***}	0.429^{b***}
Null Hypothesis: unit root with individual unit root process							
IPS (W Stat)	-0.012^{b***}	-55.728^{b***}	-0.01^{b***}	-12.887^{a***}	-2.305^{a**}	-93.483^{b***}	-96.639^{b***}
Null Hypothesis: no unit root with common unit root process							
Hadri Z-stat.	-0.236^{b}	-2.505^{b}	-1.0948^{b}	-3.7478^{b}	-9.1170^{b}	9.2766***	4.7878***

Note: *a* and *b denote* stationarity at level and at first difference respectively, while ***, **, * indicate statistical significance at 1%, 5% and 10% respectively. All the variables here are expressed in natural logs except i_t^d .

4.0 Results and Discussions

We assess the impact of prices of three main crude oil benchmark (Brent, WTI and Dubai) on stock prices of non-integrated firms in upstream and downstream sectors of global oil supply chain controlling for the underlying effect putative macroeconomic drivers of stock-oil price relationship. The empirical strategy outlined in Section 3 accounts for possible asymmetry in stock-oil price nexus for firms in both sectors of the supply chain, and for all the three oil benchmarks. The empirical results are reported for each crude oil benchmark under two sectoral headings: Upstream sector (Drilling & E&P firms) and Downstream sector (R&M and S&T firms) for cognate versions of the model without and with asymmetry for both the long- and short- run controlling for the role macroeconomic drivers play in global stock-oil price nexus in Tables 3 and 4 respectively. Similarly, Tables 5 and 6 contain results of Drilling and E&P firms to facilitate intra-sector comparison of upstream firms, Tables 7 and 8 contain results of R&M and S&T firms in the downstream sector.

The empirical estimations were prefaced with Hausman tests to establish a robust and efficient estimator for our data. The test results and their corresponding probabilities, at the bottom rows of Tables 3 to 8, overwhelmingly reject the null hypothesis lending support to the MG estimator for majority of the inter-sector panels in Tables 3 and 4 and all the sub-sector panels in Tables 6 and 7. Specifically, the null hypothesis of Hausman tests were rejected for results of each of the six panels in Tables 3, 4, 6 and 7, three sub-sector panels out of six in Table 5, and two out of six in Table 8. Therefore, results in columns (2), (4) and (6) of Table 5 and columns (2) and (4) of Table 8, we use the PMG estimates while the rest of result are MG estimates.

4.1. Stock price-oil price response- inter-sector results (sector panels)

Tables 3 and 4 present empirical results on relationships between stock prices of oil firms in Upstream and Downstream sectors of the supply chain and benchmark crude oil prices and key macroeconomic variables without and with asymmetries respectively. It should be noted that coefficients of long- and short- run relationships are respectively presented in Panels A and B of each table. Much of the discussion in this section would focus on of stock price response to crude oil prices because literature on stock price- macroeconomic variable nexus are legion see for example Ewing and Thompson, 2007; Henriques and Sadorsky, 2008; Narayan and Narayan, 2010;

Sadorsky, 2012; Bondia, et al., 2016; Raza, et al, 2016, Salisu et al., 2017. The coefficients in the first column under Panel A of Table 3 show long-run adjustments of the stock prices of Upstream and Downstream firms stock prices to prices of the three benchmark crude oils. The coefficients are statistically significant but show diametrically opposite directions of response (signs) for Upstream and Downstream firms' stock prices to crude oil prices in the long-run. Interestingly, prices of all the three benchmark crude oils exert upward pressure on stock prices of firms in the Upstream sector, but exert downward pressure on stock prices of their Downstream counterparts. There are also notable differences in (absolute) magnitude of elasticities of stock price response to changes in prices of different crude oils between the two sectors.

Specifically, the results show that if prices of Brent, WIT and Dubai crudes increase by 1%, stock price of upstream firms would, on average, increase by 0.75%, 0.87% and 0.54% respectively. However, a 1% increase in prices of the three crudes respectively contribute to 0.20%, 0.11% and 0.19% average decrease in stock prices of downstream sector firms. In the long-run, oil price exerts greater positive impact on stock price of upstream sector firms in the supply chain. These results contrast with negative and relatively smaller impact oil price exerts on stock price of downstream firms.

[Insert Table 3 about here]

The short-run coefficients indicate instantaneous adjustments in changes of stock price to short-run changes in benchmark crude oil prices and amidst changes underlying global macroeconomic variables. As notable in Table 3 is the reversal of direction of response from negative for long- run estimates in Panel A to positive for short-run in Panel B for downstream sector firms' stock response to Brent and WTI crude oil prices. However, this contrast is not replicated for Dubai crude, which retains negative sign on short and long-run, and not noticed in upstream firms. However, the magnitude of impact varies in terms of short-run elasticities. For example, a 1% increase in Brent crude prices in the short term on average led to 0.22% increase in stock prices of firms in the upstream sectors, and 0.06% increase of stock prices of downstream sector firms. Similarly, stock prices of Upstream and Downstream sector firms in the short term increased by 0.23% and 0.44% respectively following a 1% increase in WTI crude prices. Overall, the above results show that oil prices have greater positive short- and long-run impact on stock prices of firms in upstream sector, but negative and relatively smaller impact on stock prices of their counterparts in the downstream sector.

We introduce asymmetry in the modelling framework to account for possible effect of oil price shocks on stock prices of firms operating in both sectors of the supply chain in results presented in Table 4. The coefficients in the top rows under Panels A and B of Table 4 show that both positive and negative oil price shocks exercised positive long- and short-run effects on stock prices of upstream sector firms, which maintained upward momentum following shocks in prices of all the three crude oils. These results in conjunction with those in Table 3 indicate that stock prices of upstream sector firms display symmetric response to oil price shocks. However, the direction of response of stock prices of downstream firms to shocks in oil prices appears rather mixed for the three benchmark crude oil types. For Brent crudes, positive and negative price shocks exert concomitant positive and negative pressure on downstream sector firms stocks in both the short- and long-run, albeit by a statistically insignificant among in the long run. However, both positive and negative shocks to WTI crudes prices exert upward pressure on stock prices of downstream sector firms in the long run, while stock price response mirrored positive and negative price shocks in the short run. For Dubai crude oil, positive and negative price shocks induced downward trend in downstream sector firms' stock price in the long run which contrasts with WTI, but similar direction of response in the short-run. WTI crude is generally regarded as the bellwether of global crude oil prices by oil traders and researchers. These findings further raise a question on over reliance on WTI index which implicitly assumes that that oil market is 'one great pool' (Adelman, 1984, p.5, Giulietti, etl al 2014)), open a debate on weighted average for a global index.

[Insert Table 4 about here]

Similarly, stock prices of downstream sector firms saw upward movement following positive shocks in Brent and WIT crude prices in both long- and short-run. However, positive shocks in Dubai crude prices exercised upward pressure on stock prices of downstream sector firms in the short- run, but downward pressure in the long run. Moreover, there is a noticeable difference in the magnitudes of upstream and downstream sector firms' stock price response to positive and negative shocks in oil prices. For example, a positive shock leading to 1% increase in Brent crude price in the long-run produced a 2% increase in stock price of upstream sector firms, but far smaller 0.17% increase for their downstream counterparts. On the contrary, a negative shock producing a 1% fall in Brent crude oil price induced 1% increase in stock price of upstream firms, and 0.1% decrease in stock price of downstream sector firms. The error correction terms accompanying short-run estimates in Panel B of Tables 3 and 4 are all negative and highly statistically significant

These contrasts in direction and scale of upstream and downstream firms' stock price response to shocks in oil price underscore marked sectoral dichotomy in the supply chain. Stock prices of firms in upstream and downstream sectors of the supply chain respond differently to prices of different crude oils. These results imply that investors should not perceive assets of firms operating in upstream and downstream sectors of the oil supply chain as belonging to analogous asset class with similar risk profile for portfolio section purposes. Consequently, we argue that investors should not have homogenous expectation of the variance of returns on stock of firms in upstream and downstream sectors when underlying crude oil prices are taken into account.

Results in Tables 3 and 4 further show error correction coefficients for short-run estimates (in top rows Panel B) models without and with asymmetry respectively. The negative and high statistically significant error correction coefficients suggest strong disequilibrium feedback emanating from long-run changes in oil price and macroeconomic variables impacting on stock prices of firms in both sectors of the supply chain— possibly indicating co-integrating relationship in our model. In addition, the error correction terms indicate that in the short-run stock price of firms in both sectors revert to equilibrium for all crude oils following a price shock.

4.2. Stock price-oil price response- intra-sector results (sub-sector panels)

The empirical results in Tables 5 and 6 compare the response of stock prices of Drilling and E& P sub-sector firms (upstream sector) of changes in oil prices; while Tables 7 and 8 similarly compare R&M and S&T firms (downstream sector). The layout of results in the tables are similar to Tables 3 and 4; Tables 5 and 7 are based on models without asymmetry while results in Tables 6 and 8 account for asymmetry.

A discernable positive pattern generally remains for both Drilling and E&P firms of the upstream sector in relation to their stock price response to changes in oil prices in the long-run, except the negative response of E&P firms stocks to Dubai crude albeit insignificant (see Table 5). The results in Panel B confirm strong positive co-movement between stock prices of both Drilling and E&P firms with all benchmark crude oil prices in the short-run—similar to upstream whole sample results. However, interesting pattern is observed in the strength and magnitude of long-run stock-oil price response between the two sub-sectors and among crude types. The elasticities of response Drilling firms' stock prices are much larger than E&P firms for all three crude oil types, and are statistically significant for both Brent and WTI crudes. Moreover, E&P firms' stock prices displayed significant response to WTI benchmark, but not to Brent and Dubai benchmarks. When asymmetry is taken into account in the comparison, some interesting results appear in Table 6. The magnitudes of long-run elasticities of response of E&P firms' stock prices are much larger than (nearly double) their Drilling counterparts for both positive and negative shocks in prices of all three crude benchmarks. However, the short-run response of stock prices of firms in the two sectors are similar. These results indicate that stock prices of E&P sector firms tend to respond more strongly to long-run shocks in oil prices.

The theoretical and statistical interpretation of the influence of the error correction terms and macroeconomic control variables remain unchanged. Results in Tables 5 and 6 are in line with a priori expectations of the relationship between stock prices and macroeconomic variables, which largely conform to existing literature.

Tables 7 and 8 report results of models without and with asymmetry respectively for both R&M and S&T firms. Results in Table 7 confirm general long-run negative trend in the response of stock prices of R&M and S&T firms to oil prices shown in the whole sample result in Table 3. Specifically, R&M responded significantly to Brent and Dubai crudes prices in the long run. However, in the short-run S&T firms stock price co-movements with oil prices of the three benchmark crudes were positive and statistically significant. Nonetheless, R&M sector firms stock prices respond negatively to Dubai benchmark crude oil prices in the short run. When asymmetry is introduced in the modelling framework, R&M and S&T firms stock price response to shocks (both positive and negative) in prices of the three benchmark crudes in Table 8 is somehow mixed. The coefficients on all the long-run estimates for S&T firms stock price response to positive shocks in all crude oils are generally positive, but significant at 5 percent only for Brent crude. However, R&M firms' stock prices show contrasting positive and negative responses to positive shocks in WTI and Dubai benchmark crude oil prices respectively. Some interesting patterns emerge for R&M and S&T stock price response to negative shocks in oil prices in Panel A of Table 8 albeit discernible statistical insignificance of all the coefficients. Negative stock to Brent and Dubai crude prices induced a fall in stock prices for both R&M and S&T firms in the long run. However, negative shock to WTI crude price induced a rise in stock prices of R&M and S&T firms in the long run. The short-run results in Panel B of Table 8 show two interesting and unequivocal patterns: first, positive shocks to prices of all crudes produced a rise in stock prices of R&M and S&T firms indicating that increases in oil prices benefit downstream sector firms in the short run. Second, negative shocks to oil prices of three benchmark crudes induce negative response (fall) in stock price of R&M firms but positive response (rise) in S&T firms stock price in the short run.

4.3. Stock price – oil price response during pre- and post-global financial crisis periods

We further extend our analyses to capture the role of changing market conditions. This involves restructuring the full data into two sub-samples described as Pre- and Post-Global Financial Crisis (GFC), periods using September 2007 as a demarcation point. The choice of these two market conditions is motivated by the evidence in the literature indicating that the crisis significantly affected the behaviour of stock returns (see for example, Anagnostidis et al., 2016; Jin, 2016). For instance, Jin (2016) find that most of the returns exhibit a long memory in the 2008 financial crisis period but not in the tranquil periods, indicating that the 2008 financial crisis has adversely affected the efficiency of Asian stock markets. Also, Anagnostidis et al. (2016) note that in periods of financial instability, the herding behaviour of market agents may lead to abnormal price movements and, in turn, significant amounts of market inefficiency. Thus, we also hypothesize differing responses of stock prices of both the upstream and downstream firms to changes in oil price under the tranquil and crisis periods.

(A) Pre-GFC scenario and the Full Sample estimates

We report the regression results for both the pre-and post-GFC periods in Tables 9 and 10 respectively. We find that the results for the symmetric scenario during the pre-GFC period are similar to the full sample estimates both in the long run and short run. For instance, the response of stock price of the upstream sector firms to oil price changes is positive while it is negative for the downstream sector. Like the full sample results, the magnitude of long run impact of oil price on stock returns is higher for the upstream than the downstream in absolute term while the reverse is the case in the short run. Also, notice that the response of the firms' stock returns in the short run is similar; in essence, the firms respond the same way to sudden changes in oil price since it is an unanticipated event. However, with time, the two sectors tend to diverge in their response. Meanwhile, all the other variables are correctly signed as in the full sample case both in the long run and short run.

For the asymmetric scenario, the results depict that positive and negative changes in oil price have dissimilar impact on stock returns particularly in the long run. Unlike the full sample estimates, positive oil price changes have positive influence on stock returns while the response is negative for negative oil price changes when dealing with the upstream sector. For the downstream sector however, while the impact of both positive and negative shocks is found to be identical, the firms tend to respond more to negative oil price changes than positive. This suggests that during the period of tranquillity, the investors in the two sectors exhibit heterogeneous expectations about stock returns regardless of the movements in oil price.

(B) Post-GFC scenario and the Full Sample estimates

The evidence obtained here appears to be a reverse of the pre-GFC case for the long run and short run relationships. Unlike the pre-GFC, there seems to be some level of convergence in the long run between the upstream and the downstream during crisis period while the response in the short run differs. On average, the stock returns of the firms in the two sectors seem to respond positively to changes in oil price in the long run although the reaction is more pronounced for the upstream firms than their downstream counterparts. Also, in terms of magnitude, the crisis seems to exert greater impact on stock returns of the two sectors relative to those obtained during the period of tranquillity. In the short run however, the stock market response to oil price changes varies between the two sectors; it is positive for upstream while it negative for downstream. Apparently, during the crisis period which also led to global economic slowdown, the sale of crude and refined oil which predominantly falls within the purview of the downstream sector also witnessed some downward trend.

When we account for asymmetry, stock returns of both upstream and downstream firms seem to respond identically to positive and negative oil price changes in the long run while the result is mixed in the short run. It is largely positive for the upstream while it is negative for the downstream regardless of the nature of oil price changes. As consistently observed in previous discussions, the magnitude of response is higher for the upstream firms.

In sum, three findings are discernible from the results involving the GFC sub-samples. First, the upstream and downstream sectors respond differently to changing market conditions. Second, the upstream firms react more to changing market conditions than their downstream counterparts. Thirdly, regardless of the market condition, the two oil-based stocks respond asymmetrically to changes in oil price.

Table 3: Regression results (without asymmetry) for Upstream and Downstream sectors

Panel A	**Using Brent**		**Using WTI**		**Using Dubai-Fateh**	
Long-run	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
p_t	0.754***	-0.204**	0.872***	-0.114*	0.535*	-0.187**
	(0.269)	(0.096)	(0.302)	(0.060)	(0.283)	(0.091)
e_t	-2.841***	-4.828***	-2.584**	-3.582***	-3.796***	-4.719***
	(1.078)	(0.585)	(1.203)	(0.316)	(1.116)	(0.561)
y_t	2.439***	2.316***	2.106***	1.236***	2.704***	2.126***
	(0.780)	(0.397)	(0.716)	(0.228)	(0.813)	(0.390)
π_t	-7.063***	-1.185***	-6.966***	-1.319***	-7.144***	-1.106**
	(0.982)	(0.440)	(0.975)	(0.141)	(1.004)	(0.443)
i_t^d	-0.432**	-0.308***	-0.444**	-0.100***	-0.421**	-0.306***
	(0.196)	(0.049)	(0.185)	(0.025)	(0.200)	(0.050)
Panel B						
Short run						
υ_{t-1}	-0.111***	-0.229***	-0.113***	-0.143***	-0.110***	-0.229***
	(0.006)	(0.015)	(0.006)	(0.012)	(0.006)	(0.015)
Δp_t	0.211***	0.064***	0.231***	0.044**	0.224***	-0.055***
	(0.023)	(0.016)	(0.023)	(0.018)	(0.026)	(0.020)
Δe_t	-2.234***	-0.852***	-2.142***	-1.364***	-2.205***	-1.011***
	(0.158)	(0.182)	(0.163)	(0.185)	(0.158)	(0.180)
Δy_t	0.388	-1.066***	0.321	-0.682**	0.399	-0.875**
	(0.246)	(0.381)	(0.247)	(0.286)	(0.245)	(0.375)
$\Delta \pi_t$	3.088***	-0.605	2.862***	-0.588	3.347***	1.182
	(0.743)	(1.024)	(0.727)	(0.961)	(0.720)	(1.031)
Δi_t^d	-0.059***	0.067***	-0.063***	0.062***	-0.056***	0.062***
	(0.010)	(0.016)	(0.010)	(0.015)	(0.010)	(0.016)
α_0	3.613***	5.293***	3.390***	2.767***	3.828***	5.247***
	(0.608)	(0.776)	(0.617)	(0.235)	(0.614)	(0.766)
Hausman test	21.6***	48.84***	25.32***	52.82***	54.16***	49.57***
χ_k^2[Prob]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
N	102	114	102	114	102	114
NT	20,604	23028	20,604	23028	20,604	23028

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 4: Regression results (with asymmetry) for Upstream and Downstream sectors

Panel A	Using Brent		Using WTI		Using Dubai-Fateh	
Long-run	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
p_t^+	2.087***	0.165	1.934***	0.257**	1.358**	-0.117
	(0.390)	(0.138)	(0.538)	(0.109)	(0.534)	(0.117)
p_t^-	1.096***	-0.071	1.235***	0.083	0.781**	-0.122
	(0.258)	(0.096)	(0.357)	(0.081)	(0.333)	(0.088)
e_t	-1.747*	-4.439***	-1.875	-3.832***	-3.384***	-4.552***
	(1.024)	(0.559)	(1.159)	(0.463)	(1.164	(0.539)
y_t	4.749***	2.855***	3.739***	2.528***	4.446***	2.201***
	(1.065)	(0.435)	(1.087)	(0.431)	(1.352)	(0.440)
π_t	-28.426***	-6.320***	-21.631***	-5.051***	-19.146***	-1.355
	(4.696)	(1.584)	(4.888)	(1.515)	(5.220)	(1.335)
i_t^d	-0.287*	-0.304***	-0.428*	-0.316***	-0.415*	-0.327***
	(0.163)	(0.048)	(0.223)	(0.046)	(0.224)	(0.048)
Panel B: Short run						
υ_{t-1}	-0.115***	-0.234***	-0.115***	-0.229***	-0.112)***	-0.233***
	(0.006)	(0.015)	(0.007)	(0.014)	(0.007)	(0.015)
Δp_t^+	0.211***	0.294***	0.166***	0.323***	0.287***	0.183***
	(0.034)	(0.040)	(0.037)	(0.045)	(0.036)	(0.032)
Δp_t^-	0.122***	-0.174***	0.258***	-0.246***	0.152***	-0.244***
	(0.039)	(0.037)	(0.039)	(0.043)	(0.040)	(0.040)
Δe_t	-2.207***	-0.916***	-2.120***	-1.042***	-2.250***	-1.118***
	(0.157)	(0.177)	(0.163)	(0.178)	(0.158)	(0.178)
Δy_t	-0.036	-1.093***	0.099	-1.210***	0.326	-0.762**
	(0.257)	(0.358)	(0.273)	(0.348)	(0.262)	(0.345**
$\Delta \pi_t$	3.656***	0.486	2.768***	0.294	3.575***	1.558
	(0.744)	(1.061)	(0.724)	(1.040)	(0.710)	(1.038)
Δi_t^d	-0.058***	0.068***	-0.063)***	0.068***	-0.055***	0.064***
	(0.010)	(0.016)	(0.010)	(0.016)	(0.010)	(0.016)
α_0	10.857***	7.264***	6.842***	7.051***	5.644***	4.375***
	(1.297)	(1.519)	(1.053)	(1.369)	(1.105)	(1.166)
Hausman test	11.42*	37.90***	12.43*	46.61***	35.59***	43.56***
χ_k^2[Prob]	[0.0762]	[0.000]	[0.0762]	[0.000	[0.000]	[0.000]
N	102	114	102	114	102	114
NT	20,604	23028	20,604	23028	20,604	23028

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 5: Regression results without asymmetry for Drilling and Exploration & Production firms of the Upstream sector

Panel A	**Using Brent**		**Using WTI**		**Using Dubai-Fateh**	
Long-run	**Drilling**	**E&P**	**Drilling**	**E&P**	**Drilling**	**E&P**
p_t	0.626**	0.171	0.767***	0.514**	0.462	-0.225
	(0.294)	(0.227)	(0.282)	(0.207)	(0.291)	(0.236)
e_t	-2.126**	-4.497***	-1.754	-3.260***	-2.967**	-6.259***
	(1.045)	(1.248)	(1.071)	(1.078)	(1.304)	(1.310)
y_t	3.174***	2.532***	3.003***	1.977**	3.573***	3.212***
	(0.898)	(0.861)	(0.923)	(0.789)	(0.928)	(0.906)
π_t	-3.981***	-7.848***	-3.830***	-7.928***	-4.111***	-7.597***
	(1.396)	(0.558	(1.330	(0.510)	(1.409)	(0.612)
i_t^d	-0.211*	-0.305***	-0.238**	-0.271***	-0.206*	-0.360***
	(0.121)	(0.097)	(0.117)	(0.090)	(0.121)	(0.105)
Panel B						
Short run						
υ_{t-1}	-0.142***	-0.033***	-0.145***	-0.034***	-0.139***	-0.032***
	(0.024)	(0.003)	(0.022)	(0.003)	(0.023)	(0.003)
Δp_t	0.179***	0.249***	0.211***	0.272***	0.186***	0.258***
	(0.029)	(0.028)	(0.034)	(0.028)	(0.035)	(0.031)
Δe_t	-2.340***	-2.259***	-2.190***	-2.197***	-2.329***	-2.222***
	(0.285)	(0.171)	(0.281)	(0.176)	(0.282)	(0.173)
Δy_t	0.452	0.404**	0.338	0.417**	0.486	0.357*
	(0.432)	(0.201)	(0.415)	(0.203)	(0.439)	(0.200)
$\Delta \pi_t$	1.057	3.158***	0.669	3.004***	1.491	3.291***
	(1.017)	(0.775)	(1.003)	(0.758)	(1.013)	(0.759)
Δi_t^d	0.012	-0.074***	0.009	-0.079***	0.015	-0.069***
	(0.025)	(0.010)	(0.025)	(0.010)	(0.025)	(0.010)
α_0	1.951***	1.647***	1.747	1.552***	2.262	1.782***
	(0.604)	(0.148)	(0.667)***	(0.142)	(0.636)***	(0.154)
Hausman test	22.48***	2.36	26.32***	2.63	16.33***	7.39
	[0.000]	[0.7967]	[0.000]	[0.757]	[0.0060]	[0.1929]

χ_k^2[Prob]						
N	15	87	15	87	15	87
NT	3,030	17,574	3,030	17,574	3,030	17,574

Note: The variable E&P denotes oil and gas exploration and production. * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 6: Regression results with asymmetry for Drilling and Exploration & Production firms of the Upstream sector

Panel A	Using Brent		Using WTI		Using Dubai-Fateh	
Long-run	**Drilling**	**E&P**	**Drilling**	**E&P**	**Drilling**	**E&P**
p_t^+	1.393***	2.207***	1.052***	2.044***	1.095***	1.407**
	(0.395)	(0.451)	(0.230)	(0.627)	(0.202)	(0.622)
p_t^-	0.815***	1.144***	0.690***	1.294***	0.738***	0.792**
	(0.314	(0.298)	(0.148)	(0.415)	(0.123)	(0.387)
e_t	-1.646	-1.764	-1.528**	-1.915	-1.187*	-3.550***
	(1.058)	(1.189)	(0.751)	(1.347)	(0.659)	(1.352)
y_t	4.588***	4.777***	3.897***	3.729***	4.301***	4.423***
	(1.037)	(1.237)	(0.635)	(1.264)	(0.581)	(1.576)
π_t	-16.553***	-30.473***	-11.266***	-23.256***	-11.427***	-20.407***
	(3.830)	(5.442)	(3.071	(5.691)	(2.678)	(6.086)
i_t^d	-0.167	-0.307	-0.249***	-0.474*	-0.252***	-0.451*
	(0.102)	(0.191)	(0.067)	(0.261)	(0.061)	(0.262)
Panel B						
Short run						
υ_{t-1}	-0.146***	-0.110***	-0.073***	-0.109***	-0.076***	-0.107***
	(0.024)	(0.006)	(0.019)	(0.007)	(0.022)	(0.006)
Δp_t^+	0.252***	0.204***	0.239***	0.157***	0.357***	0.274***
	(0.037)	(0.039)	(0.059)	(0.042)	(0.046)	(0.041)
Δp_t^-	0.024	0.139***	0.229***	0.276***	0.049	0.181***
	(0.056)	(0.044)	(0.051)	(0.045)	(0.069)	(0.044)
Δe_t	-2.339***	-2.184***	-2.339***	-2.110***	-2.590***	-2.216***
	(0.281)	(0.178)	(0.323)	(0.185)	(0.322)	(0.178)
Δy_t	0.040	-0.050	0.512	0.112	0.741***	0.334
	(0.346)	(0.296)	(0.555)	(0.314)	(0.532)	(0.301)
$\Delta \pi_t$	1.865*	3.965***	1.316	3.079***	2.378***	3.836***
	(0.958)	(0.853)	(0.974)	(0.829)	(0.901)	(0.813)
Δi_t^d	0.014	-0.070***	0.005	-0.075***	0.010	-0.068***
	(0.026)	(0.010)	(0.021)	(0.010)	(0.021)	(0.010)
α_0	9.232***	11.138***	3.654***	6.849***	3.637***	5.475***
	(2.222)	(1.474)	(0.949)	(1.208)	(1.052)	(1.265)
Hausman test	16.10	15.12**	8.32	20.88***	6.24	22.58***
χ_k^2[Prob]	[0.0132]**	[0.0132]	[0.2153]	[0.000]	[0.3973]	[0.000]
N	15	87	15	87	15	87
NT	3,030	17,574	3,030	17,574	3,030	17,574

Note: The acronym E&P denotes oil and gas exploration and production firms. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 7: Regression results without asymmetry for Retail and Marketing and Storage & Transportation firms of the Downstream Sector

Panel A	Using Brent		Using WTI		Using Dubai-Fateh	
Long-run	**R&M**	**S&T**	**R&M**	**S&T**	**R&M**	**S&T**
p_t	-0.204**	-0.204	0.042	-0.112	-0.163*	-0.225
	(0.099)	(0.192)	(0.089)	(0.176)	(0.096)	(0.178)
e_t	-6.219***	-2.689**	-4.998***	-2.271**	-5.987***	-2.772**
	(0.603)	(1.092)	(0.487)	(0.920)	(0.560)	(1.077)
y_t	1.444***	3.651***	1.155***	3.547***	1.223***	3.508***
	(0.373)	(0.792)	(0.363)	(0.773)	(0.343)	(0.801)
π_t	-2.144***	0.287	-2.217***	0.185	-2.074***	0.379
	(0.278)	(0.997)	(0.269)	(0.980)	(0.287)	(0.999)
i_t^d	-0.127***	-0.585***	-0.141***	-0.564***	-0.123***	-0.588***
	(0.035)	(0.101)	(0.036)	(0.095)	(0.034)	(0.103)
Panel B						
Short run						
υ_{t-1}	-0.317***	-0.093***	-0.311***	-0.092***	-0.319***	-0.092***
	(0.017)	(0.009)	(0.016)	(0.009)	(0.017)	(0.009)
Δp_t	0.026	0.120***	0.006	0.119***	-0.171***	0.121***
	(0.025)	(0.014)	(0.022)	(0.015)	(0.023)	(0.015)
Δe_t	-0.483*	-1.418***	-0.746***	-1.419***	-0.746***	-1.419***
	(0.275)	(0.157)	(0.278)	(0.155)	(0.275)	(0.162)
Δy_t	-1.441**	-0.491**	-1.475**	-0.469**	-1.124*	-0.494**
	(0.614)	(0.201)	(0.632)	(0.201)	(0.606)	(0.201)
$\Delta \pi_t$	-0.770	-0.352	-1.741	-0.244	2.167	-0.327
	(1.634)	(0.698)	(1.664)	(0.636)	(1.636)	(0.694)
Δi_t^d	0.123***	-0.018**	0.124***	-0.021***	0.113***	-0.017**
	(0.024)	(0.007)	(0.024)	(0.007)	(0.024)	(0.007)
α_0	9.010***	-0.408	7.496***	-0.454	8.940***	-0.416
	(1.030)	(0.434)	(0.923)	(0.407)	(1.012)	(0.432)
Hausman test	31.91***	37.41***	33.18***	29.68***	30.62***	27.29***
χ_k^2[Prob]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
N	69	45	69	45	69	45
NT	13938	9,072	13938	9,072	13938	9,072

Note: The acronyms R&M and S&T denote Retail and Marketing and Storage & Transportation firms respectively. * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 8: Regression results with asymmetry for Retail and Marketing and Storage & Transportation firms of the Downstream sector

Panel A	**Using Brent**		**Using WTI**		**Using Dubai-Fateh**	
Long-run	**R&M**	**S&T**	**R&M**	**S&T**	**R&M**	**S&T**
p_t^+	0.010	0.439*	0.154**	0.416	-0.203**	0.017
	(0.136)	(0.251)	(0.072)	(0.254)	(0.090)	(0.263)
p_t^-	-0.098	-0.076	0.122	0.025	-0.104	-0.147
	(0.104)	(0.157)	(0.081)	(0.166)	(0.092)	(0.176)
e_t	-5.947***	-2.124**	-4.928***	-2.144**	-5.790***	-2.640***
	(0.588)	(0.849)	(0.484)	(0.857)	(0.555)	(1.011)
y_t	1.713***	2.689***	1.384***	4.276***	1.068***	3.931***
	(0.328)	(0.689)	(0.422)	(0.822)	(0.385)	(0.894)
π_t	-4.555***	-9.749***	-3.103***	-8.022**	- 0.266	-3.013
	(1.302)	(3.642)	(1.069)	(3.446)	(0.941)	(3.063)
i_t^d	-0.170***	-0.505***	-0.215***	-0.470***	-0.193***	-0.533***
	(0.040)	(0.076)	(0.044)	(0.092) *	(0.042)	(0.095)
Panel B						
Short run						
υ_{t-1}	-0.325***	-0.034***	-0.317***	-0.094***	-0.323***	-0.096***
	(0.017)	(0.004)	(0.016)	(0.009)	(0.017)	(0.009)
Δp_t^+	0.435***	0.071**	0.488***	0.072**	0.236***	0.104***
	(0.057)	(0.029)	(0.064)	(0.033)	(0.047)	(0.033)
Δp_t^-	-0.370***	0.140***	-0.494***	0.136***	-0.484***	0.123***
	(0.044)	(0.028)	(0.051)	(0.026)	(0.044)	(0.028)
Δe_t	-0.607**	-1.503***	-0.809***	-1.400***	-0.923***	-1.416***
	(0.268)	(0.152)	(0.274)	(0.156)	(0.273)	(0.161)
Δy_t	-1.380**	-0.422**	-1.580***	-0.641***	-0.896	-0.556***
	(0.572)	(0.204)	(0.555)	(0.219)	(0.554)	(0.210)
$\Delta \pi_t$	0.992	-0.265	0.662	-0.268	2.757*	-0.280
	(1.692)	(0.704)	(1.671)	(0.638)	(1.647)	(0.680)
Δi_t^d	0.124***	-0.030***	0.126***	-0.020***	0.116***	-0.017**
	(0.024)	(0.008)	(0.024)	(0.007)	(0.025)	(0.007)
α_0	10.691***	1.678***	10.434***	1.859*	6.950***	0.421
	(2.356)	(0.179)	(2.079)	(0.968)	(1.777)	(0.878)
Hausman test	18.69***	1.85	19.49***	16.92***	19.92***	84.62
χ_k^2[Prob]	[0.005]	[0.9327]	[0.003]	[0.005]	[0.0029]	[0.000]
N	69	45	69	45	69	45
NT	13938	9,072	13938	9,072	13938	9,072

Note: The acronyms R&M and S&T denote Retail and Marketing and Storage & Transportation firms respectively. * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 9: Regression results for Pre-Global Financial Crisis

Table 9a: Regression results (without asymmetry) for Upstream and Downstream sectors

Panel A	**Using Brent**		**Using WTI**		**Using Dubai-Fateh**	
Long-run	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
p_t	0.346*	-0.230*	0.330*	-0.143	0.171	-0.531***
	(0.201)	(0.123)	(0.171)	(0.120)	(0.285)	(0.161)
e_t	-2.227	-5.657***	-1.934	-5.797***	-2.886**	-5.203***
	(1.428)	(0.733)	(1.454)	(0.682)	(1.153)	(0.903)
y_t	5.535***	4.214***	6.025***	3.506***	6.238**	6.688***
	(1.865)	(1.557)	(1.757)	(1.361)	(2.611)	(2.368)
π_t	-0.411	-0.788	-0.124	-1.121	-0.501	0.014
	(2.082)	(0.745)	(2.073)	(0.716)	(1.693)	(0.728)
i_t^d	-0.369**	-0.409***	-0.371***	-0.399***	-0.377**	-0.422***
	(0.164)	(0.067)	(0.161)	(0.062)	(0.167)	(0.097)
Panel B						
Short run						
υ_{t-1}	-0.200***	-0.402***	-0.205***	-0.407***	-0.192***	-0.398***
	(0.011)	(0.023)	(0.011)	(0.023)	(0.011)	(0.023)
Δp_t	0.045*	0.278***	0.070**	0.294***	0.036	0.148***
	(0.025)	(0.036)	(0.029)	(0.037)	(0.030)	(0.031)
Δe_t	-0.856***	-0.179	-0.836***	-0.057	-0.847***	-0.145
	(0.207)	(0.205)	(0.210)	(0.209)	(0.201)	(0.207)
Δy_t	-0.718	-3.466***	-0.829*	-3.446***	-0.753*	-3.026***
	(0.448)	(0.804)	(0.449)	(0.773)	(0.440)	(0.756)
$\Delta \pi_t$	4.498***	-2.249	4.197***	-2.358	5.218***	0.471
	(0.802)	(1.489)	(0.817)	(1.512)	(0.767)	(1.376)
Δi_t^d	-0.000	0.111***	0.001	0.112***	-0.006	0.096***
	(0.015)	(0.025)	(0.015)	(0.025)	(0.014)	(0.025)
α_0	-4.048*	15.737***	-4.164**	16.545***	-6.022***	12.089***
	(2.189)	(4.203)	(2.062)	(4.138)	(2.183)	(3.818)
Hausman test	46.33***	40.88***	40.71 ***	33.33***	67.81 ***	26.10***

χ_k^2[Prob]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
N	102	114	102	114	102	114
NT	8,976	10,032	8,976	10,032	8,976	10,032

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 9b: Regression results (with asymmetry) for Upstream and Downstream sectors

Panel A	Using Brent		Using WTI		Using Dubai-Fateh	
Long-run	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
p_t^+	1.060***	-0.040	1.051***	-0.051	1.009***	-0.129
	(0.225)	(0.159)	(0.261)	(0.175)	(0.270)	(0.153)
p_t^-	-1.335***	-0.245**	-0.305*	-0.104	-0.641***	-0.420***
	(0.223)	(0.115)	(0.172)	(0.159)	(0.242)	(0.153)
e_t	0.448	-5.565***	1.098	-6.149***	0.360	-5.376***
	(0.780)	(0.666)	(1.562)	(0.912)	(1.074)	(0.773)
y_t	14.412***	2.834**	9.007***	1.646	12.519***	4.031**
	(1.819)	(1.390)	(1.596)	(1.862)	(1.980)	(1.793)
π_t	-38.510***	-3.664	-18.595***	-1.434	-22.977***	-3.900
	(4.751)	(2.546)	(4.747)	(3.623)	(4.326)	(2.510)
i_t^d	0.291***	-0.264***	-0.030	-0.276***	0.005	-0.233***
	(0.091)	(0.050)	(0.129)	(0.053) *	(0.103)	(0.054)
Panel B: Short run						
υ_{t-1}	-0.077***	-0.413***	-0.219***	-0.416***	-0.199***	-0.405***
	(0.005)	(0.023)	(0.013)	(0.023)	(0.012)	(0.023)
Δp_t^+	0.131***	0.486***	-0.057	0.312***	0.076	0.397***
	(0.046)	(0.069)	(0.055)	(0.066)	(0.053)	(0.060)
Δp_t^-	-0.071	0.011	0.114**	0.218***	-0.062	-0.116**
	(0.050)	(0.047)	(0.057)	(0.059)	(0.056)	(0.052)
Δe_t	-0.993***	-0.038	-0.906***	-0.038	-0.842***	-0.109
	(0.201)	(0.213)	(0.216)	(0.211)	(0.204)	(0.206)
Δy_t	-0.785*	-3.654***	-1.135**	-3.828***	-1.202***	-3.602***
	(0.423)	(0.772)	(0.448)	(0.752)	(0.437)	(0.732)
$\Delta \pi_t$	6.099***	-0.559	4.933***	-1.438	5.894***	1.302
	(0.878)	(1.380)	(0.833)	(1.417)	(0.769)	(1.311)
Δi_t^d	-0.058***	0.067***	-0.022*	0.086***	-0.035***	0.056**
	(0.012)	(0.025)	(0.013)	(0.025)	(0.013)	(0.025)
α_0	9.968***	25.710***	3.845	24.135***	2.402	21.725***
	(0.627)	(6.994)	(3.818)	(6.289)	(3.522)	(5.918)
Hausman test	10.36	22.19 ***	18.54***	55.37***	14.82**	37.80***
χ_k^2[Prob]	[0.1103]	[0.000]	[0.000]	[0.000]	[0.022]	[0.000]
N	102	114	102	114	102	114
NT	8,976	10,032	8,976	10,032	8,976	10,032

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 10: Regression results for Post-Global Financial Crisis
Table 10a: Regression results (without asymmetry) for Upstream and Downstream sectors

Panel A	Using Brent		Using WTI		Using Dubai-Fateh	
Long-run	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
p_t	0.990***	0.404***	0.743***	0.362***	0.826***	0.483***
	(0.121)	(0.070)	(0.099)	(0.056)	(0.111)	(0.067)
e_t	0.853	0.285	-1.185*	-0.281	0.003	0.780***
	(0.677)	(0.293)	(0.681)	(0.276)	(0.666)	(0.273)
y_t	2.056***	2.078***	1.437**	1.985***	2.277***	2.141***
	(0.550)	(0.341)	(0.575)	(0.343)	(0.545)	(0.331)
π_t	-11.758***	-4.895***	-9.774***	-4.339***	-11.575***	-5.023***
	(1.238)	(0.932)	(1.151)	(0.903)	(1.213)	(0.902)
i_t^d	-0.278***	-0.378***	-0.188***	-0.368***	-0.260***	-0.381***
	(0.053)	(0.043)	(0.056)	(0.043)	(0.054)	(0.042)
Panel B						
Short run						
υ_{t-1}	-0.240***	-0.296***	-0.243***	-0.292***	-0.241***	-0.299***
	(0.011)	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)
Δp_t	0.305***	-0.247***	0.237***	-0.143***	0.304***	-0.279***
	(0.045)	(0.045)	(0.038)	(0.035)	(0.042)	(0.049)
Δe_t	-1.944***	-1.352***	-1.921***	-1.025***	-1.955***	-1.517***
	(0.199)	(0.258)	(0.194)	(0.288)	(0.194)	(0.259)
Δy_t	0.042	-0.728	0.275	-0.843*	0.130	-0.742*
	(0.310)	(0.446)	(0.325)	(0.435)	(0.310)	(0.446)
$\Delta \pi_t$	-1.185	-0.777	1.995*	-2.257***	-0.791	-0.463
	(1.173)	(0.693)	(1.048)	(0.716)	(1.142)	(0.755)
Δi_t^d	-0.016*	0.122***	-0.035***	0.122***	-0.010	0.117***
	(0.009)	(0.017)	(0.010)	(0.017)	(0.009)	(0.017)
α_0	10.798***	6.597***	11.034***	6.239***	11.201***	6.042***
	(1.539)	(1.371)	(1.588)	(1.373)	(1.541)	(1.391)
Hausman test	39.42 ***	66.04***	39.35 ***	45.53***	37.62 ***	54.50***
χ_k^2[Prob]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

N	102	114	102	114	102	114
NT	11,628	12,996	11,628	12,996	20,604	12,996

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

Table 10b: Regression results (with asymmetry) for Upstream and Downstream sectors

Panel A	**Using Brent**		**Using WTI**		**Using Dubai-Fateh**	
Long-run	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
p_t^+	0.983***	0.324***	1.016***	0.562***	0.983***	0.433***
	(0.149)	(0.116	(0.143)	(0.169)	(0.149)	(0.104)
p_t^-	0.857***	0.406***	0.791***	0.501***	0.874***	0.495***
	(0.109)	(0.079)	(0.091)	(0.093)	(0.107)	(0.075)
e_t	0.794	0.304	-1.527**	-0.328	-0.101	0.819***
	(0.671)	(0.313)	(0.689)	(0.312)	(0.626)	(0.298)
y_t	3.409***	1.856***	2.060***	1.414***	2.657***	1.965***
	(0.424)	(0.400)	(0.636)	(0.508)	(0.593)	(0.404)
π_t	-8.162***	-3.040*	-14.265***	-4.313*	-13.598***	-3.595**
	(1.861)	(1.772)	(2.547)	(2.212)	(2.405)	(1.728)
i_t^d	-0.318***	-0.388***	-0.097**	-0.363***	-0.197***	-0.389***
	(0.053)	(0.046)	(0.048	(0.057)	(0.045)	(0.045)
Panel B: Short run						
υ_{t-1}	-0.074***	-0.325***	-0.273***	-0.319***	-0.276***	-0.329***
	(0.007	(0.014)	(0.012)	(0.013)	(0.012)	(0.014)
Δp_t^+	0.471***	-0.050***	0.131**	0.179***	0.288***	-0.079***
	(0.061)	(0.049)	(0.056)	(0.054)	(0.055)	(0.054)
Δp_t^-	0.428***	-0.396***	0.284***	-0.499***	0.253***	-0.440***
	(0.060)	(0.064)	(0.057)	(0.072)	(0.060)	(0.068)
Δe_t	-2.232***	-1.478***	-1.696***	-1.232***	-1.905***	-1.688***
	(0.203)	(0.245	(0.199)	(0.279)	(0.199)	(0.245)
Δy_t	0.128	-0.487	-0.075	-0.669*	0.018	-0.516
	(0.256)	(0.377)	(0.383)	(0.385)	(0.344)	(0.366)
$\Delta \pi_t$	-2.179**	-0.727	2.185*	0.100	-0.142	-0.624
	(1.041	(0.841)	(1.119)	(0.881)	(1.210)	(0.926)
Δi_t^d	-0.045***	0.126***	-0.033***	0.115***	-0.007	0.122***
	(0.009)	(0.018)	(0.010)	(0.020)	(0.009)	(0.017)
α_0	1.782***	3.760	17.242***	4.998	15.721***	3.755
	(0.181)	(3.211)	(3.088)	(3.451)	(3.172)	(3.272)
Hausman test	6.26 *	64.75***	34.97***	15.16***	36.84***	60.59 ***
χ_k^2[Prob]	[0.3950]	[0.000]	[0.000]	[0.019]	[0.000]	[0.000]
N	102	114	102	114	102	114

NT	11,628	12,996	11,628	12,996	11,628	12,996

Note: * p<0.1; ** p<0.05; *** p<0.01. Nob is number of observations. Values in ( ) and [ ] represent standard errors and probability values respectively. The number of cross-sections and total panel observations are respectively symbolized as N and NT. The χ_k^2 is the chi-squared statistic with k degree of freedom which is determined by the number of estimated parameters in the long-run equation of the heterogeneous panel.

5.0 Concluding remarks

The literature on relationships between oil prices and equity prices often tend to focus on large, vertically integrated multinational oil firms whose operational activities cut across the length and breadth of global oil supply chain. In this paper, we analyse response of stock prices of specialized non-integrated firms in upstream and downstream sectors of oil supply chain to crude oil price using three leading benchmark crudes. The analyses were extended to stock-oil price relationships Pre- and Post-GFC periods. The theoretical approach was underpinned by the arbitrage pricing theory which provides a framework for understanding stock-oil price relationships in conjunction with key global macroeconomic factors.

The first phase of data analyses on panels of Upstream and Downstream sectors separately account for possible asymmetry in stock-oil price relationships in both the long and short-run for each of the three crude oil benchmarks. In the second phase, we extended the empirical strategy to sub-sectors namely Drilling and E&P constituents of the upstream sector and S&T and R&M constituents of the downstream sector. The final phase of the analyses partitioned the data into pre-GFC and post-GFC sub-samples and compared stock-oil price nexus under changing market conditions which emanated from the global financial crisis.

The results unequivocally show significant contrasting directions of response of stock prices of Upstream and Downstream sector firms to crude oil prices in the long-run. Specifically, the results reveal increases in stock price of upstream sector firms following increases in prices of all three benchmark crude oils in the long-run; which contrasts with downstream firms' stock price response. Also, the elasticities of stock price response to changes in price of different crude oil benchmarks is (in absolute terms) larger for upstream sector firms than their downstream sector counterparts. In the short-run, the results show that stock prices of firms in both sectors adjusted instantaneously to oil prices though stock prices of downstream sector firms respond positively to increase in oil prices, which contrasts their long-run behaviour. The results further show that positive and negate shocks to prices of all three benchmark oil prices have symmetric positive long- and short-run effects on stock prices of upstream sector firms; however the direction of response of stock prices of downstream firms to shocks in oil prices is rather mixed for the three benchmarks. Findings from sub-sector analysis generally confirm positive pattern of response of stock prices of Drilling and E&P firms (upstream sector) to all benchmark crude oil prices in both the long- and short-run, while the S&T and R&M sub-sectors offer contrasting results.

The above findings imply that investors and fund managers should not perceive assets of upstream and downstream sectors as similar risk and return profile for portfolio diversification purposes. Therefore, we conclude that shocks to crude oil prices have differential impact on stock prices of firms in upstream and downstream sectors of oil and gas supply and that stock prices of firms in the same sector respond uniformly to crude oil prices or hold homogenous expectation of variance and returns on stock of firms in both sectors.

Findings on stock price response to changing market conditions caused by GFC show that the upstream and downstream sectors respond differently to changing market conditions. However, the upstream firms react more to changing market conditions than their downstream counterparts, but stocks of both sectors respond asymmetrically to changes in oil price irrespective of market conditions.

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