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Investigating the sources of Black's leverage effect in oil and gas stocks

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Abstract: The Black's leverage effect hypothesis postulates that a negative stock return innovation increases the financial leverage of a firm since the value of equity decreases at a given level of debt, which, in turn, creates a higher equity return volatility in the future. The paper is aimed at investigating the authenticity of the Black's leverage effect hypothesis and the relationship between negative stock returns and the financial leverage of the UK oil and gas stocks from 2004 to 2015. For each stock, exponential generalised autoregressive conditional heteroscedasticity model was estimated using Fama–French–Carhart 4-factor asset pricing model to extract the difference between the effects of negative and positive stock return innovations, regarded as leverage effect. The leverage effect parameter was further regressed on the financial leverage ratios of the book value of long-term debt to total assets, interest expenses to total assets and long-term debt to market value of equity to examine whether variation in the leverage parameter was as a result of variation in the firm's financial leverage. The findings of the study show that Fama-French-Carhart four risk factors of market, size effect, value and momentum were significant in the stock returns of most of the oil and gas companies. The mixed results in the significance level of the factors were attributed to the differences in individual firm characteristics. An evidence of leverage effect was also found in all the oil and gas stock returns but no evidence to suggest it was derived from the changes in the

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PUBLIC INTEREST STATEMENT

Stakeholders such as investors and financial managers of oil and gas companies would be interested in identifying the key factors that are responsible for the behaviour of stock returns. This would enable the stakeholders to make sound investment and financing decisions. One of the established behaviours of stock returns is their potential for high fluctuations due to negative changes caused by relevant bad news or information. Investigating the causes of such bad news and the subsequent over-responsiveness of the stock returns are the main objectives of this paper. The financial risk of the oil companies measured by the level of debt in the capital structure is considered to be among the sources of bad news due to the perceived high-risk equity holders are exposed to. The study tested whether the level of debt is responsible for the high fluctuations of the stock returns at a time of negative changes.

financial leverage of the companies. The implication of these findings for financial managers in the oil and gas industry was that while asset pricing frameworks such as CAPM and its extensions are relevant in determining oil stock returns, the level of gearing is irrelevant, albeit it has been recognised as one of the determinants of the firm's level of risk.

Subjects: Economics, Finance, Business & Industry; Finance; Industry & Industrial Studies

Keywords: Black's leverage effect; EGARCH; size effect; book-to-market value; debt-to-total assets; interest expenses-to-total assets; long-term debt-to-market value of equity; Fama-French-Carhart

JEL classifications: G10; G12

1. Introduction

The Black (1976)'s leverage effect hypothesis postulated an inverse relationship between stock returns and future volatility, and thus if stock returns are negative, equity value decreases and leverage increases given a fixed level of debt in company's capital structure (Hasanhodzic & Lo, 2011). The hypothesis has been tested several times since its genesis by many researchers but still, no consensus of whether the negative stock return innovations induce the level of firm's financial leverage or vice versa (Dufour, Garcia, & Taamouti, 2012; Engle & Ng, 1993; Ericsson, Huang, & Mazzotta, 2016). Among the early researchers that tested Black's proposition was Christie (1982). The scholar investigated the contribution of several variables to the volatility of stock returns and discovered that financial leverage and interest rates have a positive correlation with stock returns. Specifically, financial leverage was identified to be responsible for volatility asymmetry. Scholars such as Smith (2015) have observed the weaknesses of the findings of Christie (1982) to include the use of homoscedasticity assumption in modelling stock returns. The advent of autoregressive conditional heteroskedasticity model by Engle (1982) and its generalisation by Bollerslev (1986), has established the existence of conditional heteroskedasticity in stock returns, which made the assumption of homoskedasticity (as in Christie, 1982) unrealistic. However, the assumption of conditional heteroskedasticity has also been adopted by scholars such as Cheung and Ng (1992) and Long, Tsui, and Zhang (2014), but still supported the findings of Christie (1982). In a contrary opinion, Figlewski and Wang (2000) documented several anomalies with the proposition that leverage effects are due to financial leverage. Their study confirmed the existence of leverage effect in stock returns but attributed its cause to "down market effect". The causes of volatility asymmetry have also been traced to trading activity that has been guided by information asymmetry between well informed and uninformed investors in the market, (Avramov, Chordia, & Goyal, 2006), and market-wide factors such as market-level volatility innovations, market-wide cash flows, market-level leverage and world's stock return (such as CRSP index) as suggested by Dennis, Mayhew, and Stivers (2006). The argument of whether the level of a financial leverage in a company contributes to the established volatility asymmetry or leverage effect in its stock returns continues, with scholars such as Smith (2015) supporting the argument, and scholars such as Hasanhodzic and Lo (2011) opposing the position. Many approaches have been adopted by scholars to measure the leverage effect in stock returns and its determinants but very little evidence of the use of 4-factor pricing model in such analyses was found in the literature (Bekaert & Wu, 2000; Christie, 1982; Daouk & Ng, 2011; Duffee, 1995; Hasanhodzic & Lo, 2011; Smith, 2015).

In this paper, Fama-French-Carhart risk factors are used in an EGARCH process to observe whether the volatility asymmetry would still be significant in explaining the stock returns of the UK oil and gas companies. The variance between the effect of positive and negative stock return innovations was computed as a leverage effect parameter, which was regressed on financial leverage variables to assess the possible existence of any association. The contribution of the paper lies in the application of Fama/French/Carhart 4-factor model including the momentum factor in the EGARCH process to measure the leverage effect in the oil and gas stock returns; the construction of the leverage effect parameter; and the measure of the relationship between the financial leverage variables and the series of leverage effect parameter using M-estimation in the regression model to address the non-normality in the series of the constructed leverage effect parameter. The study addresses the three subsectors (exploration and production, integrated oil and gas and oil equipment and services) of the UK oil and gas industry separately to observe whether the behaviour of the variables under consideration could be attributed to the identified subsectors.

Section 2 reviews the existing literature on volatility asymmetry, Black's leverage hypothesis and financial leverage ratios as risk factors in explaining stock returns and the volatility asymmetry. Section 3 discusses the data of oil companies under study and the methodology adopted in the study. The empirical estimations made and results generated are discussed in Section 4, while Section 5 presents the concluding remarks of the paper.

2. Review of literature

The study by Black (1976) was conducted on the daily stock returns of thirty companies, mostly the constituents of Dow Jones Index from 1964 to 1975. The main aim of the study was to investigate the relationship between stock returns and changes in volatility in both the individual stocks and their respective portfolio. An inverse relationship was observed between volatility changes and stock returns. Volatility tends to increase more with any decrease in stock returns. The relationship was described in two forms: direct causation, in which the changes in stock returns cause the changes in volatility; and reverse causation, in which volatility changes dictates the movement of the stock returns. In the direct causation, a decrease in stock returns causes a decline in firm's equity value, which in turn, causes an increase in debt to equity ratio and future volatility. While, in the reverse causation, external factors such as technology risk cause the increase in volatility if the firm's return on investment is negatively affected, and the consequence would be the decrease in stock returns. In trying to test the validity of Black's hypothesis, various methodological modifications have been made and findings were found to be either accepting or rejecting the hypothesis (Cox & Ross, 1976; Ericsson et al., 2016; French, Schwert, & Stambaugh, 1987; Gallant, Rossi, & Tauchen, 1992; Linton, Whang, & Yen, 2016; Pindyck, 1984).

Early criticism of the methodology adopted by Black (1976) came from Christie (1982), in which, the scholar raised a concern about the inadequacy of the sample size used in Black's study. Christie conducted a robust test on 379 stocks compared to the 30 stocks used by Black. Notwithstanding, the validity of the Black's leverage hypothesis was confirmed. Although, Smith (2015) believes that with the assumption that expected stock returns are constant, and their volatility is homoscedastic and non-autocorrelated, the findings in Christie (1982) might be invalidated. Duffee (1995) also observed that using a broader set of sample size will make the results in Christie (1982) disappear. Other tools used in testing Black's hypothesis include conditional heteroscedasticity models (Bollerslev, Litvinova, & Tauchen, 2006; Cheung & Ng, 1992; Engle & Ng, 1993; Linton & Mammen, 2005; Long et al., 2014; Nelson, 1991; Rodriguez & Ruiz, 2012), a nonparametric measure of conditional distributional dominance (Linton et al., 2016), a panel vector autoregression model (Ericsson et al., 2016), and using Fama and French risk factors in the EGARCH process to estimate the leverage effect parameter (Adami, Gough, Muradoglu, & Sivaprasad, 2010; Smith, 2015). Adami et al. (2010) have also confirmed the existence of an inverse relationship between stock returns and leverage but became weaker when Fama-French-Carhart's risk factors were used to estimate returns.

Hasanhodzic and Lo (2011) have strongly disputed the opinion that Black's leverage effect is due to the variation in the level of financial leverage. The scholars used a sample of all equity-financed companies over a period of 36 years between 1972 and 2008. The same method and regression variables used in both Black (1976) and Christie (1982) were adopted in the study, and the empirical results generated suggest that leverage effect in the stock returns investigated were as strong, if not stronger, as that in the stock returns of companies that have financial leverage. The validity of Hasanhodzic and Lo (2011)'s findings could also be disputed for the fact that the scholars ignored the presence of operating leverage, which is as a result of fixed costs that remain constant in a firm over a short run.

The causes of leverage effect in stock returns have also been ascribed to factors other than the level of firm's financial leverage. Avramov et al. (2006) have proposed a trading-based explanation for volatility asymmetry in stock returns. They identified the trading activity that has been guided by information asymmetry between well informed and uninformed investors as the cause for volatility asymmetry (see also Fosu, Danso, Ahmad, & Coffie, 2016). Dennis et al. (2006) have identified broader market factors such as market-level volatility innovations, market-wide cash flows, market-level leverage and world's market index of stock returns as the cause of leverage effect in stock returns not only the level of financial leverage. A strong relationship between leverage effect and trading volume of stock has also been documented by scholars such as Choi, Jiang, Kang, and Yoon (2012).

3. Data and methodology

3.1. Data

The data of the study consist of the entire stocks under the UK oil and gas sector quoted on the main market of the London Stock Exchange. The stocks were categorised into three, based on the identified subsectors of exploration and production; integrated oil and gas; and oil equipment and services companies to enable robust analysis in the oil sector. The excess stock returns were generated by deducting the UK Treasury bill rate of return from the computed stock return series of every company from 2 January 2004, to 30 June 2015.

The Fama-French and momentum factors for UK market were adopted from those computed by Gregory, Tharyan, and Christidis (2013). Leverage effect parameter was derived from the estimation of the EGARCH model using the Fama-French and momentum factors. Financial leverage variables of the oil companies used in the study are the ratios of the book value of long-term debt-to-total assets, interest expenses-to-total assets and long-term debt-to-market value of equity downloaded from the Thomson Reuters Datastream.

3.2. Methodology

The Nelson (1991)'s exponential generalised autoregressive conditional heteroscedasticity (EGARCH) model was estimated on the individual excess stock returns of the UK oil companies using Fama-French and momentum factors to extract the Black's leverage effect. The leverage effect parameter, which represents the effect of negative stock returns innovation on the future volatility of stock returns was estimated from Equation (1).

$$R_{it} - R_{ft} = \alpha_{i0} + \beta_{im}(R_{mt} - R_{ft}) + \beta_1 \mathrm{SMB}_t + \beta_2 \mathrm{HML}_t + \beta_3 \mathrm{Mom}_t + \varepsilon_{it} \tag{1}$$

in which, $R_{it} - R_{ft}$ represents the excess return of the individual stock, where, R_{it} stands for company's daily stock return and R_{ft} as the UK Treasury bill rate adjusted to a daily rate, representing a risk-free rate of return. β_{im} is a coefficient that represents the systematic risk of the London stock exchange. $R_{mt} - R_{ft}$ represents the excess return of the market, where, R_{mt} stands for the entire market return by FTSE All Share index. SMB_t stands for Small Minus Big, which, is the difference between the small and large stock portfolio returns computed based on companies' market values. In the same way, HML_t stands for High Minus Low, which, is the difference between the high and low stock portfolio returns computed based on companies' book-to-market values. Finally, the Mom_t stands for the momentum factor under the supposition that price is more likely to be moving in the same direction without change after the impetus to change position.

In the EGARCH process, as shown in Equation (2), the conditional variance ($ln(\sigma_{it}^2)$) is always positive and exponential, even if, the other parameters (ω, α, β, γ) are negative. The gamma (γ) measures the leverage effect; if $\gamma < 0$, then there is asymmetry, and negative innovations will lead to higher volatility in the future than positive innovations ($\gamma > 0$ indicates that positive innovations generate higher volatility than negative innovations, while, $\gamma = 0$ shows symmetry).

$$\varepsilon_{it} = \sigma_{it} \cdot u_{it},\ ln(\sigma_{it}^2) = \omega + \alpha u_{it-1} + \gamma[|u_{it-1}| - E(|u_{it-1}|)] + \beta \ln(\sigma_{it-1}^2) \tag{2}$$

From the above equation, the effect of the positive and negative stock returns can be represented as:

$$g(u_{it-1}) = \begin{cases} (\alpha+\gamma)u_{it-1} - \gamma E(|u_{it-1}|) & \text{if } u_{it-1} \geq 0; \\ (\alpha-\gamma)u_{it-1} - \gamma E(|u_{it-1}|) & \text{if } u_{it-1} < 0. \end{cases} \tag{3}$$

The leverage effect or the difference between the effect of the positive and negative stock return innovations are measured by λ as in Smith (2015) as:

$$\lambda = exp^{-4\alpha} - 1 \tag{4}$$

The lambda (λ) representing the leverage effect in the stock return innovations of the oil and gas companies will be regressed on their financial leverage variables or ratios in order to investigate the variables that are responsible for the leverage effect.

In the investigation, Equation (5) was also formulated as a regression model to assess whether there is any relationship between changes in the Black's leverage effect parameter and that in the financial leverage ratios.

$$\lambda_{it} = \alpha_0 + \alpha_1(\text{BVDEBT/TA}) + \alpha_2(\text{INT(cf)/TA}) + \alpha_3(\text{LTDEBT/MVEQUITY}) + u_{it} \tag{5}$$

Huber (1973)'s M-estimation (as in Equations (6)–(9)) was adopted in the robust regression using financial leverage ratios as independent variables and leverage effect parameter as a dependent variable. The main purpose of adopting the model is to fit a model that captures the majority of the information presented by the data, most particularly capturing the non-normality of the leverage effect parameter. The specification of the M-estimator can be represented as in Muthukrishnan and Radha (2010) as:

$$\sum_{i=1}^{n} \rho(X_i, \theta) = \text{min, with respect to } \theta \in \Theta$$

$$E_{Pn}\left[\rho(X, \theta)\right] = \text{min, } \theta \in \Theta \tag{6}$$

where $\rho(X, \theta)$ represents a chosen function in which the maximum likelihood of the coefficient "θ" is covered by the M-estimator in the model $\mathcal{P} = \{P_\theta, \theta \in \Theta\}$; if $f(X, \Theta)$ represents the density function of P_θ, then the maximum likelihood estimator is the explanation of the minimisation of the following.

$$\sum_{i=1}^{n} (-\log f(X_i, \theta)) = \text{min, } \theta \in \Theta$$

with ρ being non-identical in θ in Equation (6) and having a continuous derivative $\psi(\cdot, \theta) = \frac{\delta}{\delta\theta}\rho(\cdot, \theta)$, the root ($T_n$)of the equation will be:

$$\sum_{i=1}^{n} \psi(X_i, \theta) = 0, \theta \in \Theta$$

in which;

$$\frac{1}{n}\sum_{i=1}^{n} \psi(X_i, T_n) = E_{Pn}[(X, T_n)] = 0, T_n \in \Theta \tag{7}$$

Combining Equations (6) and (7), the M-estimator (T_n) stands as the explanation of the minimisation:

$$\int_x \psi(x, T(P))dP(x) = E_p[\psi(X, T(P)] = \min, T(P) \in \Theta \quad (8)$$

The independent variables subjected to the robust regression include the basic financial leverage ratios of long-term debt to total assets; interest expenses paid per cash flow statement as adopted by Smith (2015) to overcome the problem of variation between book value and market value of debt; and long-term debt to market value of equity as adopted by Koutmos and Saidi (1995).

4. Estimation and results

Table 1 shows the descriptive statistics of the oil and gas stock returns listed on the main market of the London stock exchange. Seventy-six per cent of the total companies are incorporated in the UK. From the reported standard deviation, the stock return series of Nostrum Oil and Gas Plc was the most volatile among all the companies by a standard deviation of 0.069367 from the mean of 0.000095. Stock return series of Cadogan Petroleum, Lamprell Plc, Exillon Energy Plc, Hardy Oil and Gas, JKX Oil and Gas and Cape Plc were also found to be highly volatile.

Table 1. Descriptive statistics for the oil and gas stocks' daily returns between 2 January 2004 and 30 June 2015

Oil and gas producers (exploration and production/integrated oil and gas)

	Country of main business*	Obs.	Mean	Maximum	Minimum	SD
Exploration and production						
Cairn energy Plc	Edinburgh, UK	2,904	0.0004	0.4005	−0.2001	0.0259
JKX oil and gas	London, UK	2,904	−0.0002	0.2770	−0.2915	0.0328
Premier oil	Edinburgh, UK	2,904	0.0002	0.1589	−0.1605	0.0245
Soco international	London, UK	2,904	0.0004	0.1730	−0.4226	0.0251
Tullow oil	London, UK	2,904	0.0005	0.2163	−0.1408	0.0252
Hardy oil and gas	Douglas, Isle of Man	2,601	−0.0006	0.2579	−0.5343	0.0336
Cadogan petroleum	London, UK	1,834	−0.0016	0.3216	−0.3822	0.0487
Nostrum oil & gas Plc	London, UK	1,833	0.0001	1.0107	−0.8436	0.0694
Exillon energy Plc	Douglas, Isle of Man	1,395	−0.0003	0.2578	−0.2377	0.0341
Enquest Plc	London, UK	1,322	−0.0006	0.2097	−0.1614	0.0270
Ophir energy	London, UK	1,002	−0.0006	0.1723	−0.1610	0.0277
Integrated oil and gas						
BP	London, UK	2,904	−0.0001	0.1058	−0.1404	0.0162
Royal Dutch shell "B"	London, UK	2,904	0.0001	0.1321	−0.0982	0.0155
Royal Dutch shell "A"	London, UK	2,544	0.0000	0.1286	−0.0979	0.0153
Oil equipment and services						
Amec foster Wh. Plc	Cheshire, UK	2,904	0.0004	0.1355	−0.1507	0.0201
Hunting	London, UK	2,904	0.0006	0.1440	−0.1081	0.0232
Wood group (John)	Aberdeen, UK	2,904	0.0005	0.1602	−0.1455	0.0239
Petrofac	St. Helier, Jersey	2,512	0.0006	0.1280	−0.3072	0.0260
Lamprell Plc	Douglas, Isle of Man	2,274	−0.0001	0.1862	−0.8421	0.0426
Cape Plc	St. Helier, Jersey	1,020	−0.0007	0.1775	−0.4562	0.0343
Gulf marine serv. Plc	London, UK	323	−0.0006	0.0955	−0.1325	0.0227

*Country of main business is defined by the registered office (country of incorporation) of the companies. Oil and gas companies operate in various countries of the world, especially where oil and gas are found. Stock return series are from the oil and gas companies' securities listed on the UK main market of the London Stock Exchange, excluding those of foreign companies listed on the international main market of the Exchange.

In Table 2, the results of the Exponential GARCH model using the Carhart four-factor model as the extension of the Fama-French three-factor model with a momentum factor are shown. The

Table 2. Estimates of parameters using the exponential GARCH (EGARCH) model

Oil and gas producers (exploration and production/integrated oil and gas)

	α_{i0}	β_{im}	β_1	β_2	β_3	ω	α	γ	β
Exploration and production									
Cairn E.	−0.0004	1.2163	0.2782	0.0614	−0.0900	−0.0990	0.0862	−0.0290	0.9954
	[−1.2524]	[35.0055]	[4.7468]	[0.9356]	[−2.104]	[−15.20]	[18.706]	[−10.92]	[1076.0]
	(0.2104)	(0.0000)	(0.0000)	(0.3495)	(0.0353)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
JKX O&G	−0.0008	1.1113	0.7785	−0.1181	0.0125	−0.6660	0.2819	−0.0180	0.9361
	[−1.9307]	[24.1520]	[10.787]	[−1.696]	[0.2104]	[−22.72]	[29.899]	[−3.224]	[260.37]
	(0.0535)	(0.0000)	(0.0000)	(0.0898)	(0.8333)	(0.0000)	(0.0000)	(0.0013)	(0.0000)
Premier oil	−0.0006	1.1676	0.3748	0.2723	−0.0067	−0.1650	0.1050	−0.0200	0.9890
	[−2.0363]	[32.5280]	[6.6249]	[3.9762]	[−0.164]	[−8.137]	[10.648]	[−4.004]	[523.74]
	(0.0417)	(0.0000)	(0.0000)	(0.0001)	(0.8697)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
Soco Intl.	−0.0001	1.1139	0.4516	−0.0629	−0.0211	−0.2260	0.1266	−0.0210	0.9817
	[−0.4423]	[32.9237]	[7.7125]	[−1.085]	[−0.421]	[−11.21]	[18.012]	[−4.054]	[442.30]
	(0.6583)	(0.0000)	(0.0000)	(0.2776)	(0.6731)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
Tullow oil	−0.0002	1.3401	0.0944	−0.0742	−0.0728	−0.2380	0.1465	−0.0063	0.9832
	[−0.7236]	[36.9244]	[1.5857]	[−1.068]	[−1.542]	[−12.48]	[20.631]	[−1.240]	[437.01]
	(0.4693)	(0.0000)	(0.1128)	(0.2851)	(0.1229)	(0.0000)	(0.0000)	(0.2148)	(0.0000)
Hardy O&G	−0.0004	−0.0694	−0.0501	−0.2097	−0.0638	−0.1260	0.1016	0.0063	0.9913
	[−0.6420]	[−1.1437]	[−0.603]	[−1.874]	[−0.918]	[−11.55]	[16.776]	[2.2030]	[789.88]
	(0.5209)	(0.2527)	(0.5463)	(0.0609)	(0.3582)	(0.0000)	(0.0000)	(0.0276)	(0.0000)
Cadogan	−0.0022	0.5595	0.3949	0.0602	0.1138	−0.8190	0.3284	−0.0780	0.9050
	[−2.9058]	[7.4500]	[4.2353]	[0.4079]	[1.3976]	[−14.06]	[18.068]	[−5.750]	[117.93]
	(0.0037)	(0.0000)	(0.0000)	(0.6833)	(0.1622)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Nostrum O.	−0.0003	0.7712	1.2530	−0.5610	1.4424	−2.4150	1.1915	0.0301	0.7356
	[−0.7541]	[13.6263]	[17.799]	[−8.052]	[32.956]	[−30.22]	[38.329]	[1.1602]	[64.846]
	(0.4508)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.2460)	(0.0000)
Exillon E.	−0.0016	0.7633	0.8672	0.3934	−0.1276	−1.0320	0.2856	−0.0370	0.8801
	[−1.9242]	[9.2637]	[5.9761]	[2.6143]	[−1.118]	[−10.40]	[10.849]	[−2.611]	[70.319]
	(0.0543)	(0.0000)	(0.0000)	(0.0089)	(0.2633)	(0.0000)	(0.0000)	(0.0090)	(0.0000)
Enquest Plc	−0.0009	1.2380	0.4402	0.3734	−0.0938	−0.2980	0.1545	−0.0190	0.9761
	[−1.9290]	[21.1502]	[4.2466]	[3.3210]	[−1.216]	[−8.234]	[8.3496]	[−2.253]	[300.88]
	(0.0537)	(0.0000)	(0.0000)	(0.0009)	(0.2240)	(0.0000)	(0.0000)	(0.0242)	(0.0000)
Ophir E.	−0.0008	−0.0903	0.0274	−0.1313	−0.0059	−3.3450	0.2773	−0.1510	0.5632
	[−0.9594]	[−0.9825]	[0.1452]	[−0.656]	[−0.046]	[−6.448]	[5.7629]	[−5.332]	[8.1762]
	(0.3374)	(0.3259)	(0.8846)	(0.5118)	(0.9628)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Integrated oil and gas									
BP	−0.0003	0.8191	−0.4490	0.2442	−0.0480	−0.2900	0.1078	−0.0300	0.9769
	[−1.6191]	[41.1873]	[−15.20]	[6.6032]	[−2.148]	[−9.012]	[14.441]	[−5.444]	[319.95]
	(0.1054)	(0.0000)	(0.0000)	(0.0000)	(0.0317)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
RDS "B"	−0.0001	0.8613	−0.4510	0.1199	−0.0344	−0.1670	0.0767	0.0423	0.9882
	[−0.5319]	[48.0544]	[−15.93]	[3.8249]	[−1.787]	[−5.943]	[8.9886]	[6.6794]	[388.06]
	(0.5948)	(0.0000)	(0.0000)	(0.0001)	(0.0739)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

(*Continued*)

Table 2. (*Continued*)

Oil and gas producers (exploration and production/integrated oil and gas)

	α_{i0}	β_{im}	β_1	β_2	β_3	ω	α	γ	β
RDS "A"	−0.0002	0.0120	0.0654	−0.0076	0.0316	−0.2660	0.1397	−0.0450	0.9817
	[−0.6920]	[0.4708]	[1.5496]	[−0.150]	[0.9492]	[−7.359]	[9.6507]	[−5.517]	[286.24]
	(0.4889)	(0.6378)	(0.1212)	(0.8802)	(0.3425)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Oil equipment and services									
Amec F.	0.0001	1.0745	0.1826	0.2719	−0.0980	−0.1540	0.0795	−0.0069	0.9887
	[0.5166]	[39.0818]	[3.9954]	[5.1557]	[−3.078]	[−7.022]	[9.5726]	[−1.229]	[460.13]
	(0.6054)	(0.0000)	(0.0001)	(0.0000)	(0.0021)	(0.0000)	(0.0000)	(0.2190)	(0.0000)
Hunting	0.0000	1.1553	0.6858	0.2042	−0.1570	−0.2290	0.0919	−0.0310	0.9794
	[−0.0075]	[33.7203]	[12.142]	[3.1006]	[−4.429]	[−7.974]	[10.936]	[−5.266]	[313.55]
	(0.9940)	(0.0000)	(0.0000)	0.0019)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Wood Grp.	0.0000	1.3124	0.4034	0.2937	−0.1620	−0.1520	0.0840	−0.0083	0.9887
	[0.0398]	[37.3778]	[7.3005]	[4.4058]	[−4.225]	[−8.400]	[10.938]	[−1.559]	[530.70]
	(0.9683)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	0.1190	(0.0000)
Petrofac	0.0003	0.0879	−0.0124	−0.2280	−0.0576	−0.6920	0.1633	−0.0440	0.9224
	[0.6207]	[1.6886]	[−0.163]	[−2.251]	[−1.010]	[−9.347]	[8.0497]	[−6.289]	[110.13]
	(0.5348)	(0.0913)	(0.8705)	(0.0243)	(0.3124)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Lamprell	−0.0008	1.0743	0.9048	1.4979	−0.7400	−5.1390	0.5378	0.1874	0.2574
	[−0.8285]	[13.4502]	[8.5377]	[16.173]	[−10.41]	[−21.87]	[14.130]	[7.8780]	[7.3889]
	(0.4074)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Cape Plc	−0.0015	1.3219	1.2885	0.3847	−0.3591	−4.9200	−0.0530	−0.0970	0.2826
	[−1.0162]	[9.7847]	[4.6003]	[1.3372]	[−1.641]	[−3.800]	[−1.703]	[−3.565]	[1.5087]
	(0.3095)	(0.0000)	(0.0000)	(0.1812)	(0.1006)	(0.0001)	(0.0885)	(0.0004)	(0.1314)
Gulf marine	−0.0008	0.4510	0.0832	0.5413	−0.3706	−7.7290	0.4015	−0.0074	0.0287
	[−0.6622]	[2.3536]	[0.2878]	[1.9581]	[−1.550]	[−6.700]	[3.5482]	[−0.083]	[0.1931]
	(0.5078)	(0.0186)	(0.7735)	(0.0502)	(0.1209)	(0.0000)	(0.0004)	(0.9338)	(0.8468)

Note: The parentheses of "()" and "[ ]" represent the *p*-values and *z*-statistics based on the asymptotic standard errors respectively.

coefficients of the four-factor model seem to be significant in the determination of the oil and gas stock returns. In the exploration and production subsector, the market risk and firm's size factors were found to be significant at 5% level in all the companies except Tullow Oil (only market risk is significant), Hardy Oil and Gas Plc and Ophir Energy. Evidence of value effect was found in Premier Oil, Nostrum Oil and Gas, Exillon Energy and Ophir Energy. Momentum factor was only significant in Cairn Energy Plc and Nostrum Oil and Gas. The insignificance of momentum factor confirms the position of Fama and French (1996) that their three-factor asset pricing model captures market anomalies in most of the studies conducted except the momentum factor when considered as an additional factor in the model (Carhart, 1997; Fama & French, 1993).

All the four factors of the market risk, size and value effects, as well as momentum parameters, were significant in BP Plc of the integrated oil and gas subsector. In the same subsector, only momentum factor was not significant in Royal Dutch Shell "B" (RDSB), and none of the factors was significant in Royal Dutch Shell "A" (RDSA).

In the oil equipment and services subsector, only Petrofac and Gulf Marine companies are insensitive to the Fama-French-Carhart four-factor model. However, the evidence of the relevance of all the four risk factors was strongly found in Amec Foster Wheeler, Hunting, Wood Group (John) and Lamprell Plc. Market risk and size effect factors seem to be significant in all the oil and gas stock returns. HML factor was found to be significant in most of the stocks but the momentum factor was insignificant in the majority of the companies. The mixed results could be explained by the fact that the sensitivities of companies to Fama-French-Carhart factors are partly attributable to firm's characteristics or components (Rath & Durand, 2015). Rath and Durand (2015) have decomposed the Fama-French-Carhart factors based on firm's characteristics and discovered that a firm's sensitivity to SMB factor is determined by the firm's total liabilities; HML by market leverage; and momentum factor by both total liabilities and market leverage.

Studies have confirmed that stock returns exhibit leverage effect; a sign that negative stock return innovations increase future volatility than the same magnitude of positive stock return innovations (Ericsson et al., 2016; Koutmos & Saidi, 1995; Long et al., 2014; Smith, 2015). Our results in Table 2, have shown a high level of significance in gamma (γ) with negative coefficients (indicating a negative relationship between stock returns and volatility), demonstrating that the negative stock return innovations in the EGARCH model have more impact on future volatility than positive innovations in all the oil and gas companies except Tullow Oil, Nostrum Oil and Gas Plc, Amec Foster Wheeler, Wood Group (John) and Gulf Marine Services Plc. EGARCH specification has proven to be a strong model in explaining the stock returns of the UK oil and gas companies as parameters of the model were found to be significant in all the companies. The study went further to explore whether the changes in the companies' financial leverages are responsible for the existence of the leverage effects.

Table 3. Regression analysis to examine the significance of the financial leverage variables in the determination of leverage effect

Oil and gas producers (exploration and production/integrated oil & gas)

	α_0	α_1 (BVDEBT/TA)	α_2 (INT(cf)/TA)	α_3 (LTDEBT/MVEQ.)
Exploration and Production				
Cairn energy Plc	0.0000	0.0000	−0.0001	0.0000
	[0.7557]	[0.7294]	[−1.5879]	[−0.8051]
	(0.4498)	(0.4657)	(0.1123)	(0.4207)
JKX oil and gas	0.0005	−0.0002	0.0006	0.0000
	[1.2232]	[−1.1658]	[0.6407]	[2.1443]
	(0.2212)	(0.2437)	(0.5217)	(0.0320)
Premier oil	0.0002	−0.0001	−0.0001	0.0000
	[1.6519]	[−0.3405]	[−0.0826]	[0.0286]
	(0.0985)	(0.7335)	(0.9341)	(0.9771)
Soco international	−0.0002	−0.0003	0.0001	0.0000
	[−0.3510]	[−0.5540]	[1.3301]	[−0.5121]
	(0.7255)	(0.5796)	(0.1835)	(0.6085)
Tullow oil	0.0000	−0.0002	0.0000	0.0000
	[0.5796]	[−1.1901]	[0.9370]	[−0.3671]
	(0.5622)	(0.2340)	(0.3487)	(0.7135)
Cadogan petroleum[y]	0.0382	−0.0025	0.0018	0.0000
	[1.4591]	[−1.6007]	[1.2201]	[−0.1395]
	(0.1445)	(0.1094)	(0.2224)	(0.8890)
Nostrum oil & gas Plc	−0.0043	−0.0001	−0.0014	0.0004
	[−1.1627]	[−0.0084]	[−2.9881]	[1.2372]
	(0.2449)	(0.9932)	(0.0028)	(0.2160)

(*Continued*)

Table 3. (*Continued*)

Oil and gas producers (exploration and production/integrated oil & gas)				
	α_0	α_1 (*BVDEBT/TA*)	α_2 (*INT(cf)/TA*)	α_3 (*LTDEBT/MVEQ.*)
Exillon energy Plc	−0.0001	−0.0002	0.0001	0.0000
	[−0.1767]	[−2.1522]	[0.0848]	[2.6453]
	(0.8597)	(0.0314)	(0.9324)	(0.0082)
Enquest Plc	0.0001	−0.0003	−0.0003	0.0000
	[0.8604]	[−0.1409]	[−0.5312]	[1.8305]
	(0.3896)	(0.8879)	(0.5952)	(0.0672)
Ophir energy	−0.1618	−0.0016	0.1692	0.0000
	[−0.8226]	[−0.6012]	[0.7766]	[2.0514]
	(0.4107)	(0.5477)	(0.4374)	(0.0402)
Integrated oil and gas				
BP	0.0002	−0.0001	−0.0002	0.0000
	[0.6956]	[−0.7345]	[−0.4674]	[0.5772]
	(0.4866)	(0.4626)	(0.6401)	(0.5638)
Royal Dutch shell “B”	−0.0012	0.0001	0.0017	0.0000
	[−2.3316]	[1.7641]	[2.1802]	[−1.5685]
	(0.0197)	(0.0777)	(0.0292)	(0.1167)
Royal Dutch Shell “A”	0.0004	−0.0001	−0.0004	0.0000
	[0.9323]	[−2.0211]	[−0.4184]	[1.9842]
	(0.3512)	(0.0433)	(0.6756)	(0.0472)
Oil equipment and services				
Amec Foster Wh. Plc	0.0000	−0.0001	0.0000	0.0000
	[1.8891]	[−1.7447]	[0.2331]	[1.2788]
	(0.0589)	(0.0810)	(0.8156)	(0.2010)
Hunting	−0.0002	−0.0001	0.0001	0.0000
	[−0.3700]	[−0.5098]	[1.4491]	[0.5559]
	(0.7113)	(0.6102)	(0.1473)	(0.5783)
Wood group (John)	0.0000	−0.0001	0.0001	0.0000
	[1.1364]	[−0.9647]	[1.4159]	[0.4339]
	(0.2558)	(0.3347)	(0.1568)	(0.6643)
Petrofac	0.0002	−0.0001	0.0001	0.0000
	[1.1930]	[−0.2186]	[0.2700]	[−0.1318]
	(0.2329)	(0.8269)	(0.7871)	(0.8951)
Lamprell Plc	0.0007	0.0007	−0.0009	−0.0001
	[0.3751]	[1.2928]	[−0.8112]	[−1.0534]
	(0.7076)	(0.1961)	(0.4172)	(0.2921)
Cape Plc	0.0024	−0.0003	0.0010	0.0000
	[1.0802]	[−2.7710]	[0.5382]	[2.3486]
	(0.2800)	(0.0056)	(0.5904)	(0.0188)
Gulf marine serv. Plc	0.0024	−0.0003	0.0010	0.0000
	[1.0802]	[−2.7710]	[0.5382]	[2.3486]
	(0.2800)	(0.0056)	(0.5904)	(0.0188)
Exploration and production				
Hardy oil and gas[Z]	All equity financed	All equity financed	All equity financed	All equity financed

Note: The parentheses of “()” and “[ ]” represent the *p*-values and *z*-statistics based on the asymptotic standard errors respectively.

[Y]Companies without fixed interest long-term debt securities. For these companies, total liabilities including long-term provisions and current liabilities were used to calculate leverage.

[Z]A company with no data available for debt and therefore, considered as all-equity financed.

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Similar to Koutmos and Saidi (1995), Smith (2015), Christie (1982), Bekaert and Wu (2000) and Schwert (1989), three financial leverage ratios; book value of long-term debt to total assets; interest expenses to total assets; and long-term debt to market value of equity of the UK oil and gas companies were used as independent variables in a robust regression model to assess whether the evidence of leverage effects found in Table 2 are due to the companies' financial leverages. Table 3 shows the results derived from the coefficients of the financial leverage ratios in the model. The financial leverage ratios were found to be insignificant and irrelevant as the cause of volatility asymmetry in most of the UK oil and gas stock returns (see also, Bekaert & Wu, 2000; Koutmos & Saidi, 1995; Schwert, 1989). Debt to total assets coefficient was only significant at 5% level in Exillon Energy Plc, Royal Dutch Shell "A", Cape Plc and Gulf Marine Services Plc. The problem with debt to total assets ratio due to the use of book-based values has been addressed by the incorporation of the market-based debt to market value of equity ratio and cash flow-based ratio of interest expense to total assets as in Smith (2015). The market-based leverage ratio was also found to be significant in Exillon Energy Plc, Royal Dutch Shell "A" and Cape Plc, confirming that changes in financial leverage are the cause of asymmetry or leverage effect in their respective stock returns (see also, Christie, 1982; Smith, 2015). The coefficient of the cash-based financial leverage ratio (interest expense to total asset) was significant but negative in Nostrum Oil and gas Plc and Royal Dutch Shell "B". The negativity of the coefficient means an increase in financial leverage will cause a decrease in asymmetry or leverage effect (or otherwise) in the stock returns. This result also confirms that the leverage effects are not due to the changes in financial leverage.

As in Hasanhodzic and Lo (2011), leverage effects are found in Hardy Oil and Gas Plc, which is fully financed by equity, without any significant long-term debt in its capital structure over the period of the study. The coefficient of the leverage effect (asymmetry) in Hardy Oil and Gas Plc is significant and negative, and as strong as those in oil companies with a significant level of financial leverage.

5. Conclusion

The purpose and findings of the study were threefold; testing the validity of Fama–French–Carhart four-factor model on the UK oil and gas companies; testing the presence of asymmetry or leverage effect in the stock returns of the UK oil and gas companies using the EGARCH model developed by Nelson (1991); and determining whether the variations in volatility asymmetry are due to variations in the level of oil companies' financial leverage.

The risk factors in the Fama-French-Carhart model were found to be strongly relevant to the determination of oil and gas stock returns (see also Sanusi & Ahmad, 2016). However, the level of their significance or relevance among the companies varies, despite the fact that the companies are in the same class of business risk. The disparity could be due to individual firm's characteristics as suggested by Rath and Durand (2015). The scholars have called for the decomposition of the Fama-French-Carhart's risk factors to demonstrate individual firm characteristics. The effect of volatility asymmetry has been found in most of the UK oil and gas stock returns investigated. The coefficients of the leverage effect were negative and significant as hypothesised by Nelson (1991). Our results have not shown any evidence to suggest that the leverage effects are partly as a result of firm's leverage ratios. To strongly challenge Black (1976) leverage effect hypothesis, the stock return series of Hardy Oil and Gas Plc, that has no long term fixed interest debt in its capital structure has volatility asymmetry or leverage effect. On the same note, the firm's leverage ratios are not determined by the behaviour of company's stock returns but firm-specific factors such as the formation of asset structure based on the composition of tangible and non-tangible assets (Balios, Daskalakis, Eriotis, & Vasiliou, 2016). The UK oil and gas sector was investigated according to its subsectors of exploration and production; integrated oil and gas; and oil equipment and services to observe whether the behaviour of the stock returns can be attributed to the classification, and there was no any evidence of the subsector-based behaviour in the stock returns. The implication of the findings for financial managers, analysts and investors of the oil and gas industry was that while asset pricing frameworks such as CAPM and its extensions are relevant in determining oil stock returns, the level of gearing is irrelevant even though it has been recognised as one of the determinants of the firm's level of risk.

Further research can be undertaken to measure the leverage effect in the oil and gas stock returns using other asymmetric models such as the Threshold GARCH (TARCH) introduced independently by Zakoian (1994) and Glosten, Jagannathan, and Runkle (1993), the Power ARCH (PARCH) model introduced by Taylor (1986) and Schwert (1989) and the Component GARCH (CGARCH) introduced by Engle and Lee (1993). Another area that could be explored further is the decomposition of the size, value and momentum factors of the Fama–French–Carhart four-factor model to test whether the results of this study would change. Fama and French (2015) have suggested the inclusion of investment patterns as the fifth factor in the existing four-factor model that has been adopted in this study. A test of the new five-factor model using a similar methodology adopted in this study would be an invaluable innovation.

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