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The Impact of Oil Prices on Sectoral Equity Returns: Evidence from UK and US Stock Market Data

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Abstract

Results from a market model augmented for an oil factor suggest that this element does not affect every industry. The oil factor impact can be both concurrent and lagged, suggesting that new information derived from oil prices is sometimes incorporated immediately in equity prices when the impact is concurrent, and sometimes not when the impact is lagged. Apart from the Oil & Gas industry, all significantly affected returns respond negatively to oil price shocks and there appears to be some cross-country similarity. The application of GARCH modelling permitted the derivation of real oil price volatility which was then incorporated into a GARCH model for stock returns to assess whether oil volatility has explanatory power on equity returns' volatility. In general, higher oil volatility was found to lead to higher risk for impacted industry equity returns.

Keywords: GARCH; Oil Volatility; Sectoral Equities; Portfolio Diversification.
JEL Codes: C30; C58; E44; G11.

1 Introduction

For the last few decades, oil has played a key role in the global economy. In the past few years, oil prices have fluctuated driven by supply and demand events in the oil market, making the price of oil sometimes very volatile.

Since the 1970s there have been numerous studies focusing on the synchronisation of oil price changes and economic growth. A subset of these studies focused on the reaction of financial markets, particularly equity returns, to oil price shocks. Early studies were aimed at examining the future course of equity markets in relation to movements in oil prices. These studies also indirectly tested stock market efficiency. Subsequent studies focused on the relation between oil and equity prices, while recent models have incorporated volatility. The subject was either tackled using aggregate stock markets for different countries or focusing on one country but analysing industry differences.

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This study intends to firstly, verify whether a relationship exists between aggregate stock market returns and oil prices, and secondly, highlight any differences that may exist when aggregate data is sub-divided into industry indexes. Moreover, this study examines the reaction time of equity indices to changes in the oil price. The study was conducted separately for two countries, UK and US, and ten industries. The dataset was extended from previous literature in order to incorporate the recent and unprecedented financial crisis.

Results at the industry level indicate that oil has a positive effect on oil-producing sectors and a negative on oil-consuming industries; with patterns of reaction being similar across the two countries.

This study also builds on previous research where normality was only approximated in techniques like Vector Autoregressive (VAR) models (Falzon and Castillo, 2013). This was done by allowing for non-normality, and specifically, by allowing the variance to be time dependent, an ubiquitous feature of asset pricing. In particular, an extension was done in two ways: *i*) by creating an oil volatility series and *ii*) by determining whether uncertainty in oil prices, as measured by their volatility, can help explain equity returns' volatility at the industry level.

2 Literature Review

2.1 The Link between Economic Activity and Oil Prices

The first step is to examine the connection between oil prices and economic activity. In his pioneering study, Hamilton (1983) found that a negative relationship links oil prices to economic activity. Since then, this conclusion found wide empirical support in most academic literature.

The impact of oil price changes on economic activity can be examined specifically using supply-side models and demand-side models (Hamilton, 2003). Starting from supply-side models, Bohi (1991) considered a production function for aggregate output which depends on capital, labour, and energy. According to Bohi (1991), an oil price increase would have a direct negative effect on output, as higher-value inputs are needed. A parallel approach was taken by Rasche and Tatom (1977) wherein it was shown that an increase in the long run average cost of a firm will cause output to fall, depending on the importance of oil as a production input. Brown and Yücel (2002) assert that supply-side models offer the most plausible reasoning for a fall in economic activity following an oil price rise, due to the negative impact on productivity and wages.

Focusing on demand-side models, a distinction has to be made between oil-importing and oil-exporting countries. Mork (1994) and Brown and Yücel (2002) explain that higher oil prices bode well for oil-exporting economies as income, and therefore aggregate demand will increase. The opposite applies to oil-importing economies, which can potentially fall into an economic recession due to imported inflation (Mork, 1994).

Mork (1989) also studied the distinctive impacts of positive versus negative oil price shocks. It was found that an oil price increase had a greater negative impact on economic activity than any positive impact resulting from falling oil prices.

2.2 The Link between Oil Prices and Equity Prices

The economy is the main determinant of companies' earnings which are an important component in equity pricing. Therefore, it is expected that changes in oil prices impacting the economy would also ultimately cause changes in equity prices. Huang *et al*. (1996) argue that decreased payoffs to shareholders are an expectation that oil prices will have adverse effects on economic activity. The degree of the effect depends on the relative significance of oil for a particular firm, sector or country. It may also be dependent on the reaction of policy makers to oil price shocks (Clare and Thomas, 1994).

Huang *et al*. (1996) and Sadorsky (2004) also discuss the discount factor applied to companies' earnings in determining share prices. This is made up of expectations about future inflation rates and forecasts for the real interest rate. Their arguments are that an increase in the general price level, resulting from an increase in oil prices, will increase the discount factor and ultimately curtail equity prices. On the other hand, an increase in real interest rate caused by oil prices, can result in a smaller pool of feasible investments. Factors that increase the discount rate will lower equity prices.

The risk premium, which is included as a component of the discount factor, relates to the uncertainty of returns. Ferderer (1996) found that volatility in oil prices may have an unfavourable impact on economic growth as investments are postponed until new information is made available to the market.

Jones *et al*. (2004) carry out a literature survey to study alternative causes of recessions that were previously directly attributed to oil price shocks as the primary cause. The authors indicate that the most studied alternative cause is the indirect impact that oil prices may have on interest rates. Sadorsky (2004) points out three channels indicating how higher interest rates may lead to lower equity prices. The first channel is that higher interest rates lead to higher cost of loans, lower profitability, and as a consequence lower stock prices. Secondly, Sadorsky (2004) states that higher interest rates make other assets more attractive, and therefore, they have a negative impact on equity prices. Thirdly, lower involvement in financial markets may result due to the higher costs of trading, for example for margin traders.

2.3 Impacts of Oil Price Changes on Different Industries: Implications for Portfolio Construction

Fama and French (1997) using both the CAPM and the three factor model (Fama and French, 1993) analysed 48 industry returns. It was found that risk factors vary between sectors. A number of authors (Faff and Brailsford, 1999; Nandha and Faff, 2008; Arouri and Nguyen, 2010; and Arouri, 2011) explain that the response of equity prices to oil price changes depends on whether oil represents an income or is a cost contributor. This argument can also be applied to countries (Fayyad and Daly, 2011). However, Faff and Brailsford (1999) highlight a more significant factor to consider – the capacity of companies to modify prices. Other considerations include the industry competitive environment, industry concentration and approach towards hedging, which are signifi-

cant elements determining whether oil price risk can be shifted from firms to end-buyers (Arouri and Nguyen, 2010).

The fact that oil price changes have a differing impact on different sectors of the economy puts the notion of diversification under prime attention. Nandha and Faff (2008) argue that it would be difficult to fully spread risk in a portfolio, unless the portfolio includes investments that move in the same direction to oil returns. The authors suggest picking investments where oil is an income source – this would diversify against deteriorating economic conditions and falling equity markets following an adverse oil price shock. In fact, Arouri *et al.* (2011) found evidence that including oil into a well-diversified portfolio of EU and US stocks improves the risk-adjusted performance, and that oil risk exposures can be effectively hedged in portfolios made up of different sector stocks over time. Falzon and Castillo (2013) using a VAR model found no link between real oil prices and aggregate real equity returns. However, focusing on industry level returns, it was found that some sectors were completely unaffected by oil prices, the Oil & Gas industry was positively impacted while other industries were negatively affected by higher oil prices.

2.4 Oil Price Changes Vis-à-vis Stock Market Efficiency

An efficient capital market is one in which the current price of an asset fully reflects all available information about that asset (Fama, 1970). Fama identified three forms of market efficiency: weak-form, semi-strong-form, and strong-form market efficiency. A number of studies revealed lead-lag relationships between equities and several factors which could be attributed to the sluggish reaction by some equities to common factors (Lo and MacKinlay, 1990; Brennan *et al.*, 1993; and Hou, 2007).

Hamilton (1983) studied stock market efficiency in relation to oil prices by testing whether stock prices Granger-cause oil prices in the US. Results found no evidence of this. Similarly, Falzon and Castillo (2013) found that oil prices are not Granger preceded by any other variable in the system; entailing no feedback from equities to oil. These results have implications for stock market efficiency; if oil prices had been found to precede a downturn, then the notion of market efficiency implies that this information should in theory instantly be incorporated in stock prices. However, according to Hamilton (1983) agents have not recognised the link between oil prices and economic activity which explains the absence of reaction in stock prices. Indeed, Kling (1985) found evidence of market inefficiency at an industry level. Similarly, Falzon and Castillo (2013) found some form of market inefficiency as oil price changes preceded stock returns in a VAR model. However, the authors stressed that the economic strengths of this finding need to be tested using market simulations.

Huang *et al.* (1996) studied whether oil returns predate equity returns or vice-versa. The results in the study support the notion of market efficiency, with the only exception being present in oil-related equities.

2.5 Empirical Studies on Equities and Oil Prices

Chen *et al*. (1986) studied which factors are likely to have an impact on the price of assets in the context of Arbitrage Pricing Theory (APT). Oil price was included as one of the factors, however, only limited evidence was found for it to be an important factor for the years between 1958 and 1967. Using a bivariate VAR model, Kling (1985) studied the US stock market focusing exclusively on oil and equities for the period between 1973 and 1982. A Granger-causality test was applied to assess whether equity prices precede oil prices and vice-versa. Results show that the aggregate stock market could be deemed efficient as stock prices Granger-caused oil prices. However, this was not the case at an industry level.

Using a VAR model consisting of oil futures, equities (both for aggregate level and for twelve industries) and Treasury Bills, Huang *et al*. (1996) found that oil returns do not predate equity returns except for a number of oil-related companies and an oil price index. The implication is that agents cannot base their investment decisions on oil returns. With regard to oil companies, the inefficiency is small enough not to register a realisable profit.

Jones and Kaul (1996) evidenced negative repercussions on Canadian, Japanese, and US equities due to higher oil prices. A dividend valuation model was applied to determine how much of the impact of oil price changes on equity returns was being explained by changes in cash flows as measured by industrial production. For the US and Canada this notion was confirmed, but for Japan and the UK some form of irrationality was found.

Results by Sadorsky (1999) for the US, between 1947 and 1996, indicate that oil price changes are a key factor in explaining equity returns. Sadorsky (1999) proceeded to distinguish between oil price increases and decreases to determine asymmetrical impacts on returns. A GARCH(1,1) model was used to measure the impact of oil price volatility. Falzon and Castillo (2013) extended the model developed by Sadorsky (1999) by expanding the dataset, with the inclusion of the UK and decomposition of aggregate markets into ten industries. Results from 1973 to 2011 suggest that aggregate stock markets are unaffected by oil price changes. However, the decomposition into ten industry sub-indices shows that oil prices have no impact on some industries, positive impact on the Oil and Gas industry, and negative impact on others. Moreover, sluggish reactions to oil price changes were identified in a number of industries.

Park and Ratti (2008) examined fourteen countries using different oil price shock definitions. Impulse response functions (IRFs) show a negative response of equity returns to oil price shocks except for Norway where a positive correlation was found (possibly due to the country being a net-oil-producer). Papapetrou (2001) used a similar VAR model and employed IRFs to determine that oil price changes do have an impact on Greek equities.

Faff and Brailsford (1999) tested whether oil prices are an important aspect in stock returns of several industries. Oil prices were found to have an effect on equity returns but this varies depending on the industry being assessed. El-Sharif *et al*. (2005) made use of an analogous factor model applied to five UK industries. Oil price changes were only found to be important for equities related to the oil industry; other industry equities were only

minimally affected. Basher and Sadorsky (2006) found a significant relationship between oil prices and aggregate equity returns in twenty-one emerging countries. Thirty-five worldwide industry returns were examined by Nandha and Faff (2008) to find that only oil-related industries and mining benefit from rising oil prices, while all other industries move oppositely. Lee *et al.* (2012) found that oil price shocks did not impact composite indexes of G7 economies in terms of Granger causality. However, when focusing on individual sectors, oil price shocks did exert significant influences on some sector indexes for some countries. Wang *et al.* (2013), using a structural VAR model studied the response of stock markets returns to oil price shocks. Based on an IRF analysis, it was found that the response of stock market returns to oil price shocks in a country depends on the net position of the country in the global oil market and the causes of the oil price shocks. The authors also investigated the effects of oil price uncertainty on stock market returns; it was found that oil supply uncertainty is shown to significantly depress stock markets in both oil importing and exporting countries. Finally, the authors found that oil price shocks induce more market co-movement in oil-exporting countries, but not in oil-importing countries. This suggests that a portfolio of stocks in oil-importing countries provides more diversification benefits.

Arouri and Nguyen (2010) and Arouri (2011) studied the aggregate European sector indexes. An APT model with stock returns and oil prices was estimated as a GARCH(1,1) model using weekly data for different industry indexes. A link between oil price changes and equity returns is found, which varies across industries. With regards to oil volatility analysis, Arouri *et al.* (2012), using a VAR-GARCH approach found significant volatility spillover effects between oil prices and stock markets in Europe. A shock originating from the oil market leads to an increase in stock market volatility. However, oil market volatility behaves independently from stock market volatility; while a bidirectional relationship appears to exist in the US (Arouri *et al.*, 2011). A GARCH(1,1) model was also used by Elyasiani *et al.* (2010) where the impact of changes in oil return and oil return volatility on excess stock returns and return volatilities of thirteen US industries were studied. Strong evidence showed that oil price fluctuations constitute a systemic asset price risk at the sector level. The majority of the industries analysed show a significant relationship between oil futures returns distribution and industry excess returns, especially the oil user industries.

3 The Data

3.1 Data Description, Data Sources and Suitability

The research is aimed at analysing the relationship between oil prices and equity indexes in the UK and US from January 1973 to May 2011 utilising 461 monthly data points; totalling 10,249 observations. Analysis was carried out using data at the aggregate stock market level and industry level. All stock market indexes data for this period are Thomson Datastream indices, obtained from the same source, and represent total returns. This database provides decomposition of stock markets at various levels of detail. The aggregate market data is based on Level 1 – FTSE All Share Index for the UK and S&P 500 Composite for the US. The industry analysis was carried out at Level 2 detail. This provided the subdivision of the total market index into ten industries: Oil & Gas, Basic Materials, Industrials,

Consumer Goods, Healthcare, Consumer Services, Telecommunications, Utilities, Financials, and Technology. At this level of detail, a distinction can already be made between oil-user industries, oil-producer industries, and non-related industries.

The nominal oil price specification used is the US dollar denominated UK Brent Index obtained from the International Financial Statistics (IFS) provided by the International Monetary Fund (IMF), in line with the majority of literature on the topic. The British Pound per US Dollar (£/$1) exchange rate and the UK and US Consumer Price Indices (CPI) from IFS were used to transform oil prices from nominal to real.

It was decided to focus the analysis on the period after 1973 because prior to this year, in particular between 1957 and 1970, IFS data shows that the nominal Brent oil price was largely constant. With the advent of a number of events, the price of oil became more volatile and a central topic of interest. These post-1970 events include: the first oil price shock as a result of the OPEC embargo, the US oil production peak in 1970, and the breakdown of the Bretton Woods agreement.

3.2 Data Transformations

A number of data transformations (as Sadorsky, 1999) were carried out, which are described next. The UK real oil price was obtained by multiplying the UK Brent oil index to the £/$1 exchange rate and dividing by the UK CPI. Since the UK Brent oil index is denominated in dollars, the US real oil price was found by dividing the index with the US CPI. The first-differences of the natural logarithms of real oil price specifications were computed. Log-level real stock indices were computed by dividing nominal stock indexes by the relevant country CPI and then applying natural logarithms. While real stock returns were calculated by subtracting the first difference of natural logarithm of the relevant country CPI from the first difference of the natural logarithm of the various nominal stock indices.

Figure A.1 depicts the real oil prices. The main differences between the two versions of the real oil price stems from exchange rate movements and a different inflationary environment. While Figures A.2 and A.3 provide a representation of the stock indexes used (Figures in Appendix). It is clear from the kurtosis, skewness, and Jarque-Bera test in Table A.1 that the data does not follow a normal distribution. In Falzon and Castillo (2013) the normality assumption was only an approximation. However, in this study, the GARCH model will capture the leptokurtosis in the series, thereby relaxing the normality assumption.

4 Empirical Model and Results

Previous studies outlined earlier mostly made use of a VAR approach, whereby variances and the covariance of error terms are constant overtime. This assumption, although convenient, may not hold as financial time-series go through differing periods of volatility, where at times low volatility is followed by similar conditions and high volatility is followed by more volatility. Brooks (2008) attributes this phenomenon to the haphazard way information is propagated in financial markets, requiring a movement away from the assumption of a homoscedastic variance to a conditional heteroscedastic variance which

needs to be modelled. This study relaxes the assumption of constant variances by allowing the variance to be time-variant, that is, heteroscedastic, using (G)ARCH models.

Autoregressive conditional heteroscedastic (ARCH) models, developed by Engle (1982) and Generalised-ARCH (GARCH) developed by Bollerslev (1986) are a way to model the conditional heteroscedasticity. There are basically two parts to the understanding of these types of models (Agung, 2009). The first part is the conditional mean equation which looks like a conventional regression equation. The second part is the conditional variance equation where the emphasis is to model the time-dependent variance of the mean equation.

This research extends this reasoning in two ways by creating an oil volatility series (described by equations 3 and 4) and by determining whether current oil price volatility can help explain current equity returns volatility (described by equations 1 and 2).

4.1 Model Specification

A modified market model including changes in oil prices was considered to model equity returns in the mean equation (similar to Arouri and Nguyen, 2010; and Arouri, 2011). A lag of the change in the oil price is also included in the mean equation to capture the full impact of changing oil prices. This includes any delayed reaction of equity returns to changes in oil prices. The model with two factors (oil and total market returns) and lagged oil price changes can be represented as:

$$(1) \qquad SR_{ij,t} = \beta_{ij0} + \beta_{ij1}\Delta RO_{j,t} + \beta_{ij2}\Delta RO_{j,t-1} + \beta_{ij3}SRTOT_{j,t} + \varepsilon_{ij,t}$$

where:
all variables are in real terms;
β_k's (for $k = 1$ to 3) represent sensitivity of real stock returns to the three explanatory variables;
j is one of two countries and i is one of ten industries;
$SR_{ij,t}$ is the real stock returns for industry i and country j;
$\Delta RO_{j,t}$ is the change in the real oil price in time t for country j;
$SRTOT_{j,t}$ is the total market return for country j; and
ε_t is a residual assumed to be normally distributed with mean zero and variance σ_t^2.

Real stock returns volatility, $\sigma_{ij,t}^2$, was modelled as a GARCH (1,1) with the incorporation of current real oil price volatility as an exogenous variable in the variance equation, which will ascertain whether current oil volatility affects volatility of stock returns:

$$(2) \qquad \sigma_{ijt}^2 = \tau_0 + \tau_1 \varepsilon_{ij,t-1}^2 + \tau_2 \sigma_{ij,t-1}^2 + \tau_3 \sigma_{ojt}^2$$

where $\sigma_{oj,t}^2$ is the volatility of the real oil price for country j obtained as described in the next paragraph.

One of the aims of this research was to determine whether oil price volatility, as a measure of oil risk, can help explain equity returns volatility. This required another GARCH(1,1) model for real oil prices where the mean equation was specified as a simple autoregressive model similar to Sadorsky (1999). The GARCH(1,1) can be specified as:

$$(3) \qquad \Delta RO_{j,t} = \beta_{j0} + \sum_{i=1}^{k} \beta_{ji} \Delta RO_{j,t-1} + \mu_{j,t} \qquad \mu_{j,t} \sim N(0, \sigma_{oj,t}^2)$$

$$(4) \qquad \sigma_{oj,t}^2 = \alpha_{j0} + \alpha_{j1} \mu_{j,t-1}^2 + \alpha_2 \sigma_{oj,t-1}^2.$$

4.2 ARCH Suitability Test

The first step in GARCH estimation is to test the returns equations for the presence of ARCH effects. Testing involves estimating Equation (1), obtaining $\varepsilon_{ij,t}$'s, squaring them and regressing them on q lags of themselves depending on which order of ARCH effects is tested (Enders, 2010). The null hypothesis is that there is no ARCH effect present, which implies that all coefficients in front of the lagged squared residuals are jointly equal to zero.

Table 1 shows the results of the ARCH Lagrange Multiplier (LM) test carried out for order one, two, and twelve. This is standard for monthly data as it tests for the presence of ARCH effects in the first lag, jointly for the first two lags and jointly for all lags up to the twelfth lag, respectively. Except for the UK Telecommunications, US Consumer Services, and US Industrials (order one) industries, the null hypothesis is rejected at least at the ten percent level of significance, indicating the presence of ARCH effects of various orders and therefore the suitability of ARCH type models.

4.3 Real Oil Price Volatility

Oil price volatility was obtained from the application of the GARCH(1,1) model in Equations (3) and (4), selected on the basis of its parsimony, coefficients satisfying the non-negativity constraints and absence of ARCH effects at orders one, two, and twelve. This measure of volatility was then input in the GARCH model for real stock returns in (1) and (2). Table 2 shows the results of the estimation.

The GARCH(1,1) model appears to be a better framework for volatility of oil prices than a constant volatility assumption as ARCH and GARCH terms are highly statistically significant. US oil price volatility may exhibit increasing volatility overtime as the sum of α_1 and α_2 is slightly above one. However, an inspection of the volatility obtained for both the UK and the US, shown in Figure 1, clearly indicates that this is not the case as volatilities do not display clear increasing trends overtime. Moreover, the figure shows similarities of heightened real oil price volatilities which can be associated to particular events.

To further validate the oil volatility series created in this research, the correlations between the CBOE Oil Volatility Index (OVX) and both measures of oil volatility obtained for this study were measured. These are[1] 0.94 and 0.91 for the UK and US, respectively. But the added advantage of the GARCH-derived volatilities is that they stretch back to the start of the dataset.

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[1] Calculated from 2007M06 (start of «OVX») to 2011M05 and significant at 1% level.

Table 1: Pre-Estimation ARCH Test

Dependent Variable in Mean Equation[1],[2]	UK			US		
	ARCH(1)	ARCH(2)	ARCH(12)	ARCH(1)	ARCH(2)	ARCH(12)
Real Oil Price	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Oil & Gas	0.006***	0.021**	0.036**	0.004***	0.014**	0.000***
Basic Materials	0.002***	0.000***	0.000***	0.000***	0.000***	0.000***
Industrials	0.023**	0.012**	0.000***	0.143	0.003***	0.001***
Consumer Goods	0.002***	0.000***	0.000***	0.011**	0.000***	0.000***
Healthcare	0.067*	0.001***	0.000***	0.000***	0.000***	0.000***
Consumer Services	0.027**	0.011**	0.008***	0.861	0.534	0.117
Telecommunications	0.753	0.929	0.999	0.005***	0.016**	0.000***
Utilities	0.011**	0.014**	0.004***	0.001***	0.000***	0.000***
Financials	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Technology	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***

Note: *, **, and *** signify rejection of the null hypothesis at 10%, 5% and 1% significance level, respectively.

[1] Oil price: $\Delta RO_t = \beta_0 + \sum_{i=1}^{k} \beta_i \Delta RO_{t-1} + \mu_t$

ARCH(q)-test for the significance of α_i for all $0 < i \geq q$ in $\hat{\mu}_t^2 = \alpha_0 + \sum_{i=1}^{q} \propto \alpha \, \hat{\alpha} \,_i \hat{\mu}_{t-1}^2$

[2] Equity returns: $SR_{ij,t} = \beta_{ij0} + \beta_{ij1} \Delta RO_{j,t} + \beta_{ij2} \Delta RO_{j,t-1} + \beta_{ij3} SRTOT_{j,t} + \varepsilon_{ij,t}$

ARCH(q)-test for the significance of ρ_i for all $0 < i \geq q$ in $\hat{\varepsilon}_t^2 = \rho_0 + \sum_{i=1}^{q} \hat{\rho}_i \hat{\varepsilon}_{t-1}^2$.

Table 2: Volatility of the real oil price

	UK	US
β_0	−0.001	−0.003
β_1	0.111***	0.113*
β_2	−0.095**	−0.093*
β_3	−0.053	−0.022***
α_0	0.000***	0.000*
α_1	0.321***	0.417***
α_2	0.677***	0.621***
α_3	0.031	0.051
$\bar{R}_2$	0.047**	0.022**
Q(2)	0.116	0.054*
Q(12)	0.565	0.127
ARCH(1)	0.367	0.727
ARCH(2)	0.653	0.944
ARCH(12)	0.834	0.817

Note: *, **, and *** indicates rejection of the null hypothesis at 10%, 5%, and 1% respectively.

[1] Model:

$\Delta RO_{j,t} = \beta_{j0} + \sum_{i=1}^{k} \beta_{ji} \Delta RO_{j,t-1} + \mu_{j,t}, \qquad \mu_{j,t} \sim N(0, \sigma_{\sigma j,t}^2)$

$\sigma_{\sigma j,t}^2 = \alpha_{j0} + \alpha_{j1} \mu_{j,t-1}^2 + \alpha_2 \sigma_{\sigma j,t-1}^2$

Q(k) refers to Q-statistic for the test of no-serial correlation at lag k.

4.4 Real Stock Returns

The mean equation permitted the assessment of the reaction of real stock returns to concurrent and one-month lagged changes in real oil price changes, and to total market returns. While the incorporation of concurrent oil volatility as an explanatory variable in the conditional variance equation for real stock return volatility also permitted to
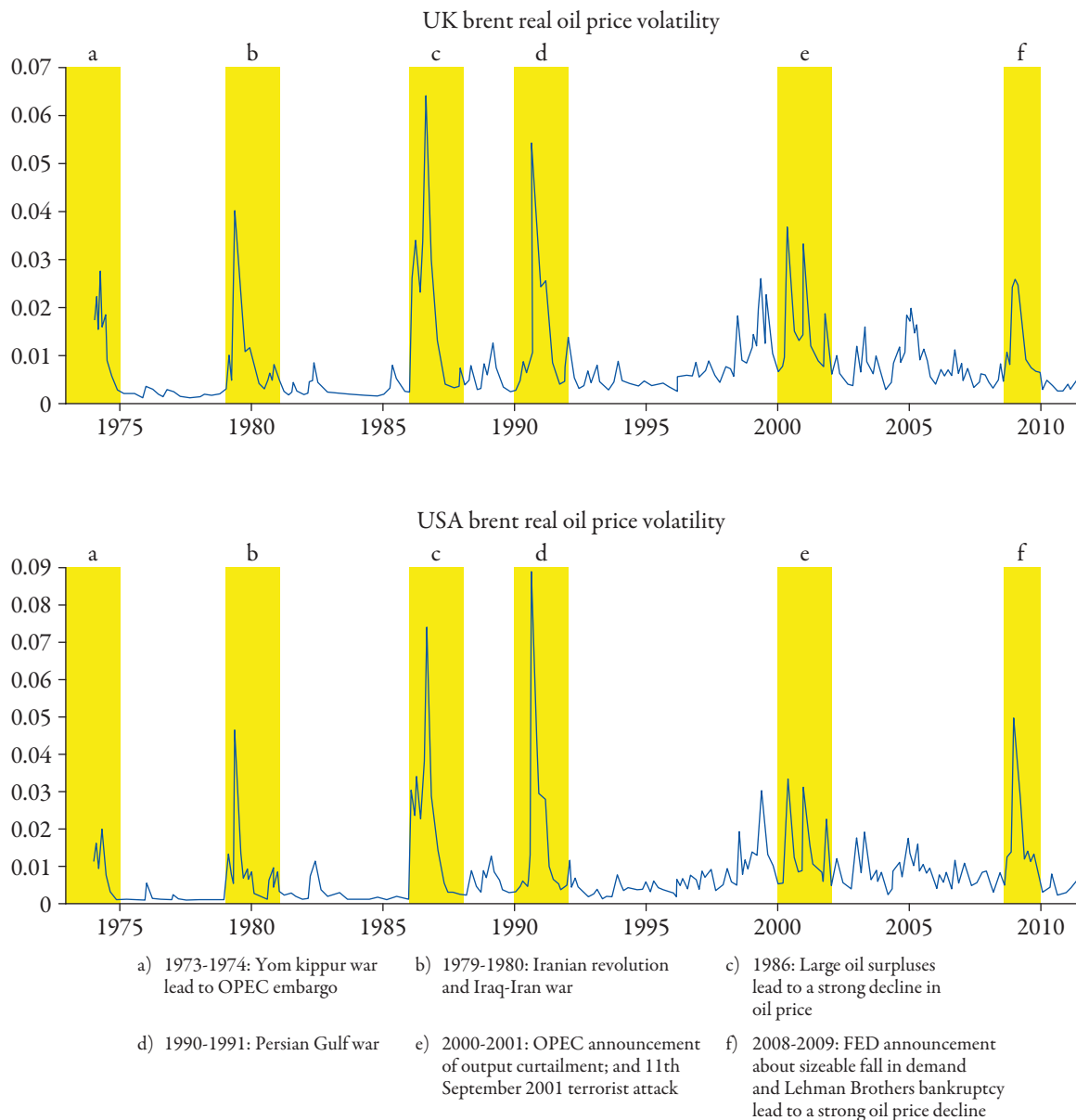
Figure 1: Oil price volatility.

analyse whether the latter is impacted by the former. Tables 3 and 4 present the results for the estimation of the GARCH(1,1) model.

Diagnostic checking of the 20 model specifications was carried out. First, second and twelfth order serial correlation was tested using the Q-statistic. With a few exceptions for the UK dataset, the null hypothesis of no autocorrelation was largely accepted at the five percent level of significance. Autocorrelation at the five percent level of significance appears to be present at least for one of the orders tested for the UK Basic Materials, Healthcare, and Utilities industries. This could have possibly been resolved by including more autoregressive terms in the mean equation. However, to maintain consistency for all 20 models and as the problem did not impact upon all lags simultaneously, this small statistical limitation was still accepted. The ARCH LM test was carried out at lags one, two, and twelve. At the five percent level of significance, the GARCH(1,1) model appears to have removed ARCH effects of all orders except for the UK *Consumer Services*

Table 3: UK Dataset GARCH(1,1) Models

	Oil & Gas	Basic Mat.	Indus.	Cons. Gds.	Healthcare
β_0	0.0032**	−0.0018	0.0008	−0.0004	0.0008
β_1	0.0907***	−0.0138	0.0007	−0.0102	−0.0615***
β_2	0.1294***	−0.0151	−0.0277	−0.0411	−0.0344**
β_3	0.9235***	1.070***	1.0355***	0.9961***	0.9128***
α_0	0.0000	0.0000	0.0000	0.0000	0.0000
α_1	0.1235***	0.168***	0.1006***	0.0945***	0.0844***
α_2	0.8585***	0.821***	0.8684***	0.8784***	0.8865***
α_3	0.0052*	0.0000	0.0007	0.0057	0.0031**
$\bar{R}_2$	0.6546	0.6931	0.7509	0.5310	0.6934
Q(1)	0.5030	0.0990*	0.1820	0.5180	0.3450
Q(2)	0.6710	0.0320**	0.3920	0.5270	0.0260**
Q(12)	0.0590*	0.2610	0.1050	0.5730	0.2360
ARCH(1)	0.3883	0.7082	0.5411	0.8387	0.7897
ARCH(2)	0.2530	0.9060	0.7683	0.9489	0.8471
ARCH(12)	0.5576	0.4103	0.0613*	0.9955	0.9151
Jarque-Bera	10.600***	3.4593	20.0300***	12.2622***	14.8498***
	Cons. Serv.	Telecoms.	Utilities	Financials	Tech.
β_0	−0.0020	0.0021	0.0054**	−0.0018	0.0019
β_1	−0.0095	−0.0555*	−0.0506*	−0.0066	−0.0265
β_2	−0.0336***	−0.0551*	0.0262	−0.0237*	−0.0096
β_3	1.0431***	0.9360***	0.656***	1.1058***	0.7744***
α_0	0.0004***	0.0003**	0.001***	0.0005***	0.0003***
α_1	0.0482	0.3851***	0.1463*	0.1519***	0.3589***
α_2	0.4653***	0.5887***	–	0.4160***	0.6219***
α_3	−0.0081***	0.0029	0.0197	−0.0112***	0.0151
$\bar{R}_2$	0.8585	0.4108	0.3753	0.8303	0.2409
Q(1)	0.8240	0.5380	0.0280**	0.4770	0.6990
Q(2)	0.9380	0.8120	0.0340**	0.6870	0.5410
Q(12)	0.0590*	0.9020	0.1020	0.4480	0.4700
ARCH(1)	0.0926*	0.5657	0.8145	0.4558	0.6833
ARCH(2)	0.0441**	0.6225	0.3976	0.0043***	0.5459
ARCH(12)	0.0091***	0.9746	0.0204**	0.0000***	0.8915
Jarque-Bera	31.7342***	479.3535***	0.3282	28.5455***	50.5270***

Note: *, **, and *** indicates rejection of the null hypothesis at 10%, 5%, and 1% respectively.
GARCH-in-Mean was tested but the term was insignificant.
AR terms were included in mean equation to correct for serial correlation (similar to Arouri, 2011).
ARCH(q) refers to ARCH test of order q with null of no ARCH effects – order of ARCH tests selected on the basis of the monthly nature of the data
Q(k) refers to Q-statistic for the test of no-serial correlation at lag k.

(order two and twelve), *Utilities* (order twelve) and *Financials* (order two and twelve) industries; while for the US, twelfth order ARCH effects may still be present for the *Oil & Gas* and *Telecommunications* industries. Arouri and Nguyen (2010) comment how GARCH modelling decreases non-normality; which in this study was prevalent in the descriptive statistics of Table A.1 as shown by the kurtosis, skewness, and Jarque-Bera test. Tables 3 and 4 confirm similar results with Jarque-Bera statistics significantly lower and the null hypothesis of normality failing to be rejected in nine cases. The Adjusted-R^2 is above 0.50 for 14 out of the 20 model specifications. The ARCH and GARCH parameters are highly statistically significant for all cases except for the ARCH terms in Consumer Services industries, UK Utilities and US Industrials industries. Furthermore, the same parameters are all positive and the sum of both parameters is less than one; as

Table 4: US Dataset GARCH(1,1) Models

	Oil & Gas	Basic Mat.	Indus.	Cons. Gds.	Healthcare
β_0	0.002	−0.0023*	−0.0004	−0.0018	0.0017
β_1	0.1543***	0.0315	0.0021	−0.0368**	−0.0420***
β_2	0.1068***	0.0203	−0.0059	−0.0460***	−0.0264*
β_3	0.7829***	1.2023***	1.1452***	0.9212***	0.8486***
α_0	0.0000	0.0001	0.0000*	0.0000	0.0000
α_1	0.1027***	0.1221***	0.0538*	0.0766***	0.0930***
α_2	0.8203***	0.8176***	0.8643***	0.8641***	0.8152***
α_3	0.0101***	0.0022	0.001	0.0046***	0.0048***
$\bar{R}_2$	0.4764	0.6826	0.8616	0.6347	0.6588
Q(1)	0.274	0.187	0.378	0.458	0.137
Q(2)	0.451	0.36	0.448	0.426	0.215
Q(12)	0.567	0.854	0.344	0.187	0.113
ARCH(1)	0.2892	0.9528	0.4914	0.2198	0.9324
ARCH(2)	0.3912	0.7017	0.6472	0.4193	0.9866
ARCH(12)	0.0315**	0.1091	0.414	0.798	0.8782
Jarque-Bera	4.2713	5.2699*	0.8819	24.9434***	6.6462**
	Cons. Serv.	Telecoms.	Utilities	Financials	Tech.
β_0	−0.0013	0.0029**	0.0031**	0.0014	−0.001
β_1	−0.0441***	−0.0251	0.0006	−0.0221	−0.0334
β_2	−0.0523***	−0.0004	0.0305	−0.0058	−0.0001
β_3	1.1171***	0.7315***	0.5345***	1.0965***	1.2025***
α_0	0.0000	0.000	0.0001*	0.0001*	0.000
α_1	0.0279	0.0831***	0.0859**	0.2252***	0.0961***
α_2	0.9175***	0.8684***	0.8307***	0.6595***	0.8565***
α_3	0.0012**	0.0051*	0.0060**	0.0039	0.0032
$\bar{R}_2$	0.8379	0.4529	0.2994	0.7302	0.676
Q(1)	0.914	0.909	0.435	0.362	0.542
Q(2)	0.989	0.965	0.619	0.607	0.728
Q(12)	0.516	0.893	0.959	0.799	0.769
ARCH(1)	0.6087	0.5211	0.2102	0.8949	0.5367
ARCH(2)	0.8901	0.8109	0.3791	0.7538	0.646
ARCH(12)	0.3950	0.0442**	0.5999	0.2411	0.2754
Jarque-Bera	7.4445**	1.7291	1.2613	2.8838	1.2446

Note: *, **, and *** indicates rejection of the null hypothesis at 10%, 5%, and 1% respectively.
GARCH-in-Mean was tested but the term was insignificant.
AR terms were included in mean equation to correct for serial correlation (similar to Arouri, 2011).
ARCH(q) refers to ARCH test of order q with null of no ARCH effects – order of ARCH tests selected on the basis of the monthly nature of the data.
Q(k) refers to Q-statistic for the test of no-serial correlation at lag k.

expected in a functioning GARCH model. The majority of the GARCH terms are very high which is very common for financial time-series and indicates strong persistence of volatility (Lamoureux and Lastrapes, 1990).

β_1 measured the concurrent impact of real oil price changes on real stock returns, which Tables 3 and 4 show not to be significant for all industry returns. The *Oil & Gas* industries are positively impacted by oil prices. The other significant impacts appear to be negative: for the UK, these are the *Healthcare*, *Telecommunications*, and *Utilities* industries; for the US, these are the *Consumer Goods*, *Healthcare*, and *Consumer Services* industries.

β_2 assessed whether lagged real oil price changes have an impact on real stock returns. Results indicate that oil price changes appear to have a delayed impact on stock returns. The same industries that exhibited a concurrent impact also registered a lagged impact

of the same sign except for the UK *Utilities* industry which only registered a concurrent impact, while the UK *Consumer Services* and the UK *Financials* industries only registered a lagged impact.

β_3 is the estimate of the sensitivity of real industry stock returns to total market returns. All coefficient estimates are highly statistically significant indicating that market returns significantly explain the various industry stock returns, albeit to various degrees. For the UK, the *Oil & Gas, Consumer Goods, Healthcare, Telecommunications, Utilities*, and *Technology* industries can be classified as defensive stock indexes given that β_3 is less than one meaning they fluctuate less than the overall market. Conversely, *Basic Materials, Industrials, Consumer Services*, and *Financials* have β_3 estimates greater than one. For the US the situation is very similar; the only difference is the *Technology* industry for which β_3 is greater than one.

α_3 is the coefficient assessing the hypothesis whether current real oil price volatility affects real stock returns volatility. Oil volatility appears to have explanatory power for a number of industries: UK: *Oil & Gas, Healthcare, Consumer Services*, and *Financials*; US: *Oil & Gas, Consumer Goods, Healthcare, Consumer Services, Telecommunications*, and *Utilities*. From these results it can be noted that with the exception of UK *Telecommunications* and *Utilities* industries, where changes in oil prices produced significant results, oil volatility also gave. For the US *Telecommunications* and *Utilities* industries, oil volatility appears to have explanatory power on returns' volatilities even though in the mean equation the oil factor did not appear to have explanatory power.

4.5   Discussion of GARCH Model Results

The results from the mean equation confirm that the oil factor does not impact every industry, the impact can be both concurrent and lagged, suggesting that firstly, some information content from oil prices is not immediately incorporated in equity prices, secondly, all significantly affected returns respond negatively to oil price changes apart from the *Oil & Gas* industry, and thirdly, there appears to be some cross-country similarity as *Oil & Gas, Healthcare*, and *Consumer Services* industries have been affected by oil price changes in both countries.

Additionally, the other aim of the research was to determine whether oil price volatility has explanatory power on equity returns volatility. Indeed, the use of this model enabled the discovery that in general, current oil price volatility affects returns volatility for a number of industries in both countries, especially where oil emerged as a significant factor in the mean equation (except the UK *Telecommunications* and *Utilities* industries). Volatility is often considered synonymous of risk and therefore this model can be interpreted as trying to measure how the risk of equity returns is also affected by oil price risks. For the US, all significant $\alpha_3's$ are positive as is the case for the UK *Oil & Gas* and *Healthcare* industries, indicating higher uncertainty about oil prices leads to higher risk. The UK *Consumer Services* and *Financials* exhibit a fall in risk as oil volatility increases; while this result is unexpected for the *Consumer Services*, for the *Financials* industry this may be due to the increased demand for hedging products (Arouri, 2011).

5 Conclusions

This research provides the analysis of oil prices and equity returns for the UK and US based on a GARCH(1,1) model.

Results for the GARCH market model extended for the oil factor generally show that various industry returns exhibited differing responses to current and one-month lagged oil price changes. Importantly from the GARCH results, it was also determined that the GARCH-derived oil price volatility could significantly explain volatility of equity returns for industries in which oil price changes where significant in the mean equation. In general, this research determined that higher oil price volatility led to higher equity returns volatility, indicating higher risks in the markets. Therefore, it can be observed that the link between equities and oil prices may not be exclusive to returns.

As stated in Falzon and Castillo (2013), the differing effects of oil prices can be due to factors like the importance of oil as a source of expenditure or revenue in particular industries, the level of price changes in response to oil price changes, hedging abilities, and oil elasticity of demand for the output of the industries. Furthermore, a similar reaction to changes in oil prices was found between the UK and the US as the sectors impacted are common in many occasions. In Falzon and Castillo (2013) this was attributed to the presence of international companies, which creates a debate between international diversification versus industry decomposition.

In assessing the results from the model, it can also be concluded that taking account of time-varying volatility in both equity and oil prices can potentially be informative in determining other equity risk drivers. Finally, another important finding is that there might be further evidence of stock market inefficiency as the lagged-oil price factor was significant in the GARCH model. However as stressed in Falzon and Castillo (2013) it is important to note that although this is a statistically significant finding, it does not automatically imply economic strength as this needs to be tested with the carrying out of market simulations involving the use of actual market conditions at the time. The results obtained may be used for portfolio construction and diversification, as varying sensitivities to oil price changes have been discovered. Avenues for further research include extending the study at a more granular level for equities, extension of the country set, and the application of new methodologies such as dynamic conditional correlation models to allow the analysis of covariance between the variables.
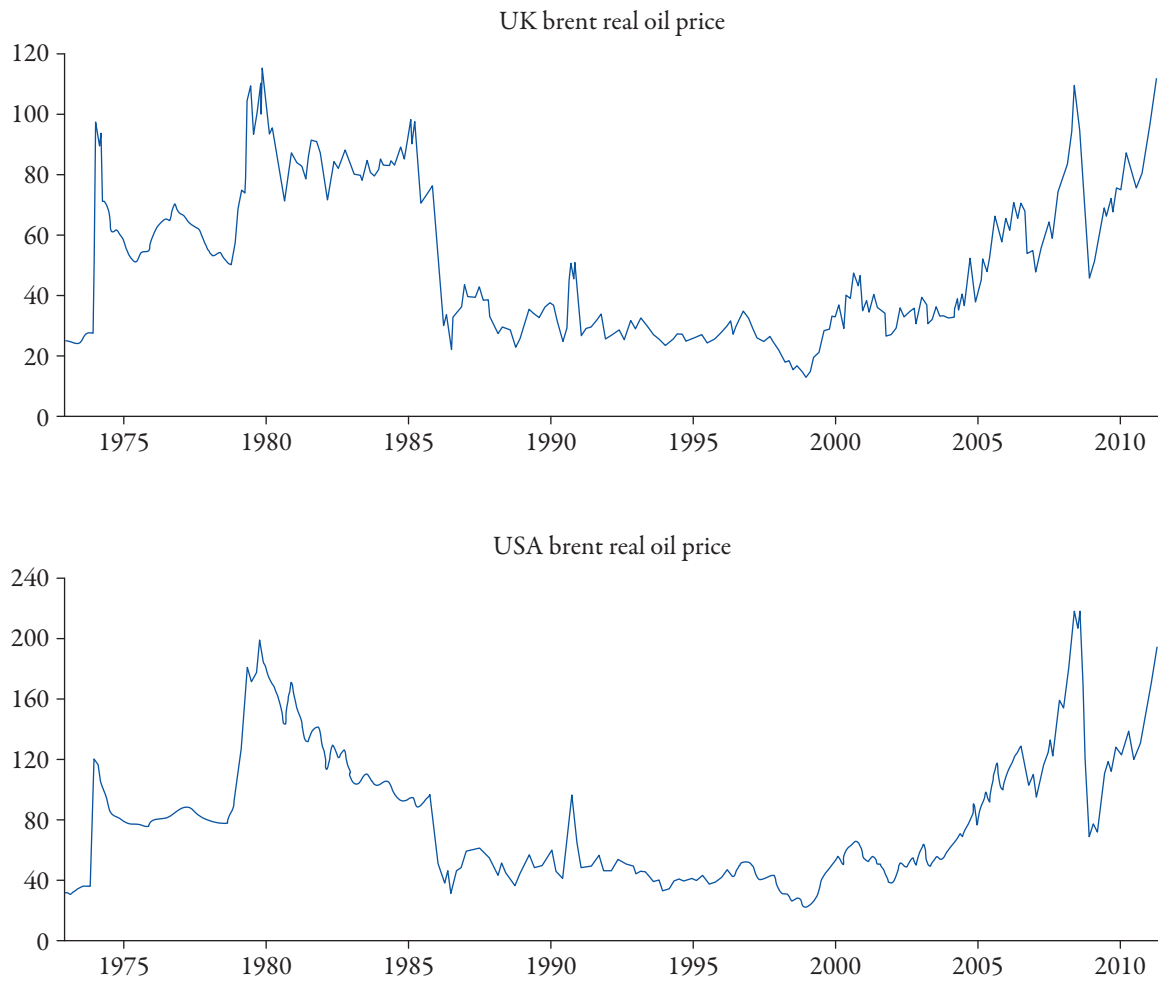
6 Appendix

UK brent real oil price

USA brent real oil price

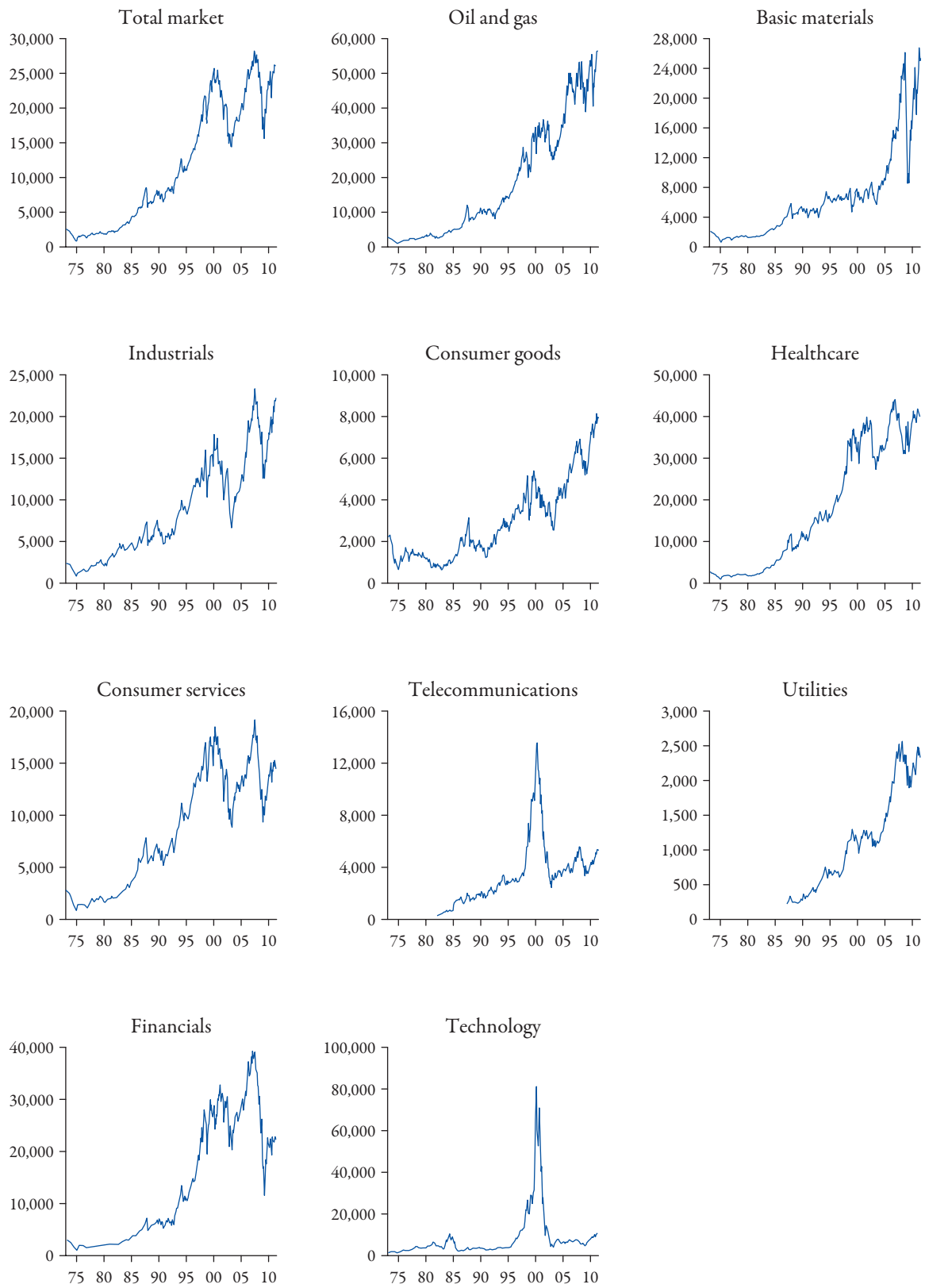Figure A.1: Real Oil Price.

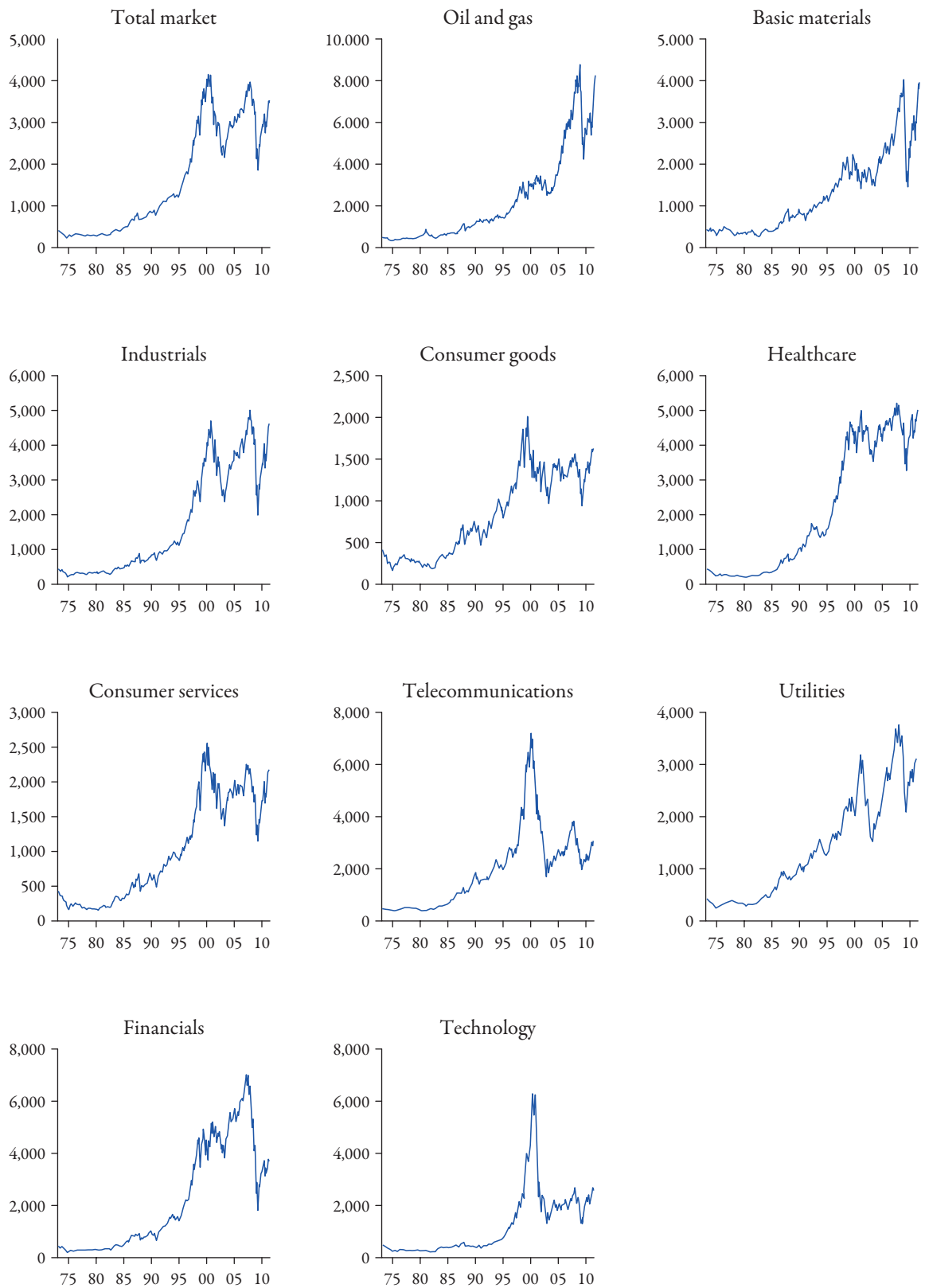Figure A.2: UK Equity Returns.

Figure A.3: US Equity Returns.

Table A.1: Descriptive Statistics for Returns Series

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.
Real Oil Price Returns									
UK	0.0033	0.0001	1.2402	−0.2772	0.1010	4.0292	51.8240	46,831.69	0.000
US	0.0040	−0.0037	1.2062	−0.2973	0.0993	3.9071	50.1243	43,638.59	0.000
UK Real Stock Returns									
Total									
Market	0.0049	0.0122	0.3928	−0.3200	0.0561	−0.0279	10.3258	1,028.70	0.000
Oil & Gas	0.0066	0.0101	0.4080	−0.3618	0.0685	−0.0249	7.0658	316.89	0.000
Basic Materials	0.0054	0.0111	0.3285	−0.4096	0.0736	−0.5597	7.3542	387.40	0.000
Industrials	0.0048	0.0094	0.3931	−0.3731	0.0682	−0.3337	7.3629	373.37	0.000
Consumer Goods	0.0027	0.0051	0.3455	−0.4315	0.0785	−0.4320	5.9635	182.64	0.000
Health Care	0.0059	0.0088	0.3691	−0.3489	0.0568	−0.1246	9.8227	893.40	0.000
Consumer Services	0.0034	0.0094	0.4083	−0.3034	0.0635	−0.1097	8.2666	532.55	0.000
Telecommunications	0.0082	0.0118	0.4799	−0.2571	0.0733	0.3774	7.7780	344.16	0.000
Utilities	0.0083	0.0106	0.1535	−0.1643	0.0503	−0.1039	3.7682	7.71	0.021
Financials	0.0041	0.0095	0.4200	−0.3221	0.0677	−0.0652	7.9391	467.88	0.000
Technology	0.0051	0.0057	0.4262	−0.4089	0.0970	−0.3707	6.0242	185.83	0.000
US Real Stock Returns									
Total									
Market	0.0046	0.0083	0.1541	−0.2395	0.0465	−0.6724	5.7049	174.51	0.000
Oil & Gas	0.0062	0.0088	0.1851	−0.1982	0.0564	−0.3725	4.2648	41.21	0.000
Basic Materials	0.0049	0.0029	0.2566	−0.3226	0.0645	−0.4985	6.4052	240.78	0.000
Industrials	0.0052	0.0080	0.1682	−0.3063	0.0567	−0.5987	5.8482	182.57	0.000
Consumer Goods	0.0031	0.0047	0.1855	−0.3153	0.0565	−0.6486	6.1199	218.34	0.000
Health Care	0.0054	0.0065	0.2276	−0.2094	0.0471	−0.3578	5.8940	169.97	0.000
Consumer Services	0.0036	0.0080	0.1799	−0.3234	0.0572	−0.6007	5.6735	164.30	0.000
Telecommunications	0.0042	0.0078	0.2647	−0.1725	0.0522	−0.1177	4.5573	47.44	0.000
Utilities	0.0044	0.0068	0.1822	−0.1854	0.0438	−0.3973	4.7048	67.66	0.000
Financials	0.0047	0.0087	0.2273	−0.3227	0.0609	−0.7275	6.8024	317.01	0.000
Technology	0.0038	0.0032	0.2198	−0.2982	0.0725	−0.3882	4.6049	60.79	0.000

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