Volatility transmissions between the petroleum market and stock sectors: Evidence from seven exporting and nineteen importing countries

Miramir BAGIROV
m.bagirov@greenwich.ac.uk
University of Greenwich, Department of Accounting and Finance
London, United Kingdom

Cesario MATEUS
cmateus@business.aau.dk
Aalborg University Business School
Aalborg, Denmark

Abstract

This study investigates the return and volatility transmissions between petroleum prices and stock sector indices of 7 net petroleum exporting and 19 net petroleum importing countries over the period from January 2005 to September 2018. Given that indices representing sectors of most considered countries are not available, a unique approach is implemented to manually construct sector indices using daily data of 5,768 stocks listed in 10 sectors. The VAR-GARCH model is applied that allows to capture bilateral volatility interactions. Furthermore, the estimates of the model are employed to analyse optimal portfolio holdings and hedge ratios. The findings reveal significant volatility transmissions between petroleum prices and stock sector indices of exporters and importers. However, the direction and magnitude of spillover effects are country- and sector-specific. The optimal portfolio weights and hedge ratios indicate that sector indices of Saudi Arabia (net exporter) and China (net importer) offer better opportunities with respect to hedging petroleum price risks.

Keywords: Petroleum exporters, Petroleum importers, Petroleum prices, Stock sector returns, Volatility transmission, Hedge ratios, VAR-GARCH

JEL Classification: G11, G12, Q43

1. Introduction

Petroleum remains the dominant source of energy that accounted for approximately 35 percent of global primary energy consumption in 2020[1] and is among the most actively traded commodities. The level of interconnection between stock markets and petroleum prices has substantially enhanced with the financialization of commodity markets. The extreme fluctuations in the price of petroleum over the past decades that were reflected with different magnitudes in stock markets have generated a particular interest among policy makers and investors. Consequently, comprehending the volatility spillover effects between petroleum prices and stock markets is essential for the efficient management of risks and investment portfolios. Given that not all sectors in the petroleum exporting and importing countries are equally sensitive to swings in petroleum prices, the utilisation of aggregate market indices in this matter would be disadvantageous. Thus, a sector level analysis can provide investors with valuable insights on diversification opportunities and help regulators in formulating relevant frameworks addressed towards the prevention of contagion risks (Bouri et al., 2016).

The number of works in the energy finance literature that study the interrelationship between petroleum price and stock market volatility has been growing. These works are primarily focused on the aggregate market indices and document different findings depending on the employed methodologies and study periods. Malik and Hammoudeh (2007) carry out one of the early works in this strand of literature. The authors investigate the transmission of volatility between the petroleum market, equity markets of the Unites States and Gulf countries, namely Bahrain, Kuwait and Saudi Arabia, over the period from 1994 to 2001. Their empirical results indicate that volatility is transmitted from the petroleum market to equity markets of all Gulf countries, but only in the case of Saudi Arabia, the spillover in the reverse direction is detected. In addition, they show the existence of volatility interactions between the second moments of the Unites States equity and petroleum markets. Other studies consider solely the United States or a group of developed markets. Mensi et al. (2013) applied the VAR-GARCH model to study the volatility linkages between the S&P 500 index and different types of commodities, including petroleum represented by both WTI and Brent grades, for the period from 2000 to 2011. Their findings show evidence of the bidirectional shock and volatility transmissions between the S&P 500 index and WTI grade, and the unidirectional spillovers of shock from the Brent sort to the S&P 500 index and volatility in the opposite course. Salisu and Oloko

[1] BP Statistical Review of World Energy 2021.

(2015) study interactions between the Brent and WTI grades of petroleum and the United States stock market for the period from 2002 to 2014 employing the VARMA–BEKK–AGARCH approach and considering structural breaks. The authors observed bilateral spillovers of shock between the studied markets, and the unilateral volatility transmissions from the petroleum market to the United States stock market before and after structural breaks. Furthermore, Ewing and Malik (2016) incorporating structural breaks in their study also report significant volatility transmissions between the petroleum prices and the United States stock market. Khalfaoui et al. (2015) investigate the volatility spillover effects between the WTI crude petroleum prices and G7 countries' stock markets over the period from 2003 to 2012. Their findings provide strong evidence of volatility linkages between petroleum and stock markets. On the contrary, Chang et al. (2013) found little evidence of volatility transmissions between crude petroleum and the NYSE, Dow Jones, FTSE 100 and S&P 500 indices employing daily data for the period from 1998 to 2009.

Other studies conduct analyses in the context of emerging markets. Arouri et al. (2011a) using the VAR-GARCH model examine the volatility interdependence between petroleum and six stock markets of the Gulf Cooperation Council countries for the period 2005-2010. Their findings indicate the existence of significant transmissions of shock and volatility between petroleum and most of the stock markets, particularly during the crisis period. Lin et al. (2014) focus on developing stock markets in the West African region, namely the GSE All-Share Index of Ghana and NSE All-share index of Nigeria. Applying different types of multivariate GARCH models they detect volatility spillovers between petroleum and stock markets of both countries. Yousaf and Hassan (2019) study return and volatility transmissions between crude petroleum and nine Asian emerging stock markets using three time periods ranging from January 2000 to May 2018. The authors show that volatility linkages vary across the considered stock markets and study periods. More precisely, the spillovers are mostly unidirectional form petroleum to stock markets during the full sample and the United States subprime crisis, and bidirectional for stock markets of India and Korea during the crash period of the Chinese stock market. Sarwar et al. (2020) investigate the volatility transmission between petroleum and stock market returns of China, Pakistan and India utilising different data frequencies over the period from July 1997 to December 2015. They provide evidence of bidirectional, unidirectional and mixed volatility spillovers for stock markets of Pakistan, China and India, respectively, and indicate that results differ across subperiods and data frequencies.

A group of works distinguish between petroleum exporting and importing countries. For instance, Wang and Liu (2016) examine volatility spillovers between petroleum and stock markets of seven petroleum exporting and nine petroleum importing economies using weekly data over the period from 2000 to 2011. Their results show the presence of volatility transmissions from petroleum to stock markets of Canada, Norway, Russia and Venezuela, while in the case of importers, the petroleum market volatility is affected by the stock market volatility of Germany, the United Kingdom and United States. Ashfaq et al. (2019) consider stock markets of three petroleum exporting countries (Iraq, Saudi Arabia, and the United Arab Emirates) and four petroleum importing countries (China, India, Japan, and South Korea). They detect shock and volatility transmissions between petroleum and stock markets of South Korea, Saudi Arabia and Iraq, but do not report significant effects in all other cases. Belhassine and Karamti (2021) investigate the volatility interactions between petroleum and stock markets of top three petroleum exporters, Canada, Russia and Saudi Arabia, and three petroleum importers, China, India and the United States, for the period from 2001 to 2017. The authors document the existence of significant price and volatility spillovers that are contingent on the studied countries and time scale. Sarwar et al. (2019) analyse the volatility transmission between crude petroleum returns and stock market returns of three large Asian petroleum importing countries, namely China, Japan and India, using daily data from 2000 to 2016. Their findings depict that spillovers of shock and volatility are unidirectional from stock market returns of India to petroleum returns, and the effects are bidirectional in the case of Japanese stock market. However, they provide no evidence for the Chinese stock market.

Given that the sensitivity to the petroleum price volatility could vary across individual sectors, some studies focus on investigating the volatility interdependencies between petroleum and stock sectors. Malik and Ewing (2009) examine the volatility and shock transmission mechanisms between petroleum prices and five stock sectors of the United States, such as Financials, Industrials, Consumer Services, Health Care and Technology. The authors employ the bivariate GARCH models and weekly data covering the period from January 1992 to April 2008. Their results show significant transmissions between petroleum prices and some of the studied sectors. Arouri et al. (2011b) applying four multivariate GARCH approaches analyse volatility interactions between petroleum and stock sectors of the United States and Europe. The authors provide evidence of the volatility transmissions, which are generally unidirectional from petroleum to global European sectors and bidirectional for sectors of the United States. These findings are corroborated by the study of Arouri et al. (2012) that investigates volatility spillovers between the Brent grade of petroleum and European sector indices over the period from 1998 to 2009. Belhassine (2020) examines the transmission of volatility between petroleum prices and nineteen Eurozone sector indices using daily data from August 2004 to August 2015. The author applies the VAR-BEKK-GARCH model and splits the main sample into three subsamples. The findings point to the heterogeneous and time varying nature of volatility spillovers between the petroleum and most Eurozone sector indices. Bouri et al. (2016) study the association between petroleum and Financials, Industrials and Services sectors in Jordan, a small petroleum importer from the MENA region, using different approaches. Their results based on the multivariate GARCH model provide evidence of long-term effects from petroleum to Industrials and Services sectors during the period preceding the Arab uprisings, and both short- and long-term transmissions from petroleum to the Industrials sector for the period that follows the Arab uprisings.

Taking into account the existing literature, the present work strives to shed new light on volatility interdependencies between petroleum and stock markets of net petroleum exporting and importing economies. To this end, an investigation is conducted at the sector level, as major stock market indices could be biased towards certain sectors, the weights of which vary depending on their importance (Mateus et al., 2017). In addition, unlike the previous studies that have been essentially devoted to the United States and aggregate European sectors, this work considers sectors of a broad sample of petroleum exporters and importers, which includes countries with different levels of economic development and degrees of petroleum dependency. International investors tend to focus on the largest and most liquid stocks within a particular or group of sectors. However, the unavailability of sector indices representing components of the employed major stock market indices causes difficulties in investigating the heterogeneity of stock sectors' responsiveness. To address this gap, following the work of Mateus et al. (2017), a unique methodology for the manual construction of stock sector indices is introduced. It is known that stock markets in each country follow their own regulatory and construction procedures. Thus, the proposed approach permits the application of the same construction methods across various markets and contribute to a more precise investigation of volatility spillover effects. The objectives of this work are twofold: (i) to examine the return and volatility transmissions between petroleum prices and self-constructed stock sector indices of seven net petroleum exporting and nineteen net petroleum importing countries utilising daily firm-level data; and (ii) to analyse optimal portfolio holdings and hedge ratios for portfolios comprising stock sector index and petroleum assets. To achieve the research objectives, the VAR-GARCH model that follows the specification of Ling and McAleer (2003) is applied, which allows to study bidirectional volatility spillovers between the considered time series. Furthermore, the obtained estimates are used to quantify optimal portfolio weights and hedge ratios based on the methodologies of Kroner and Ng (1998) and Kroner and Sultan (1993), respectively.

The present study makes several important contributions to the growing literature on volatility interconnectedness between petroleum prices and stock sectors. First, it reveals the heterogenous sensitivities of stock sector indices in the petroleum exporting and importing countries, which are generally concealed by aggregate market indices, to the petroleum price volatility that international investors and policy makers should be informed about to make efficient decisions on cross-market asset allocations, hedging risks and defining appropriate regulations. Second, in contrast to the existing industry-based researches that are region- or country-specific where a more emphasis given to developed economies, to our knowledge, it is the first study that concentrates on the analysis of both magnitude and direction of volatility spillovers between petroleum prices and manually built stock sector indices of a large set of net petroleum exporters and importers with developed, emerging and frontier markets. Third, the study introduces an innovative methodology for the construction of sector indices employing daily firm-level data, which enables to analyse accurately intermarket volatility transmission mechanisms.

Utilising daily data of 5,768 unique stocks listed from January 03, 2005 to September 28, 2018 in ten sectors, namely *Basic Materials*, *Consumer Cyclicals*, *Consumer Non-Cyclicals*, *Energy*, *Financials*, *Healthcare*, *Industrials*, *Technology*, *Telecommunications Services* and *Utilities*, of seven petroleum exporting and nineteen petroleum importing countries, the study yields interesting empirical findings. The evidence of significant shock or innovation and volatility spillovers between stock sector indices and petroleum was documented. The direction and magnitude of transmissions vary across markets and sectors. The assessment of optimal portfolio holdings and hedge ratios suggest that stock sector indices of Saudi Arabia (net exporter) and China (net importer) provide better opportunities for hedging petroleum price risks. Thus, the conducted investigation ascertains the importance of distinguishing between the net petroleum exporter and importer along with the sector level analysis in understanding the heterogeneity of spillover effects.

The remaining parts of the work are organised as follows. The next section presents the considered empirical model. Data sources, sample selection and sector indices' construction procedures are described in Section 3. Section 4 discusses the empirical findings. Section 5 analyses portfolio weights and hedge ratios. The last section finalises the work.

2. Empirical model

The GARCH models have been widely applied over the past decades by academics and practitioners to study financial volatility. It has been documented in the finance literature that the multivariate specifications of GARCH models, such as DVECH, BEKK, CCC and DCC among others, are more relevant and efficient in analysing volatility spillovers between different financial variables compared to their univariate counterparts. However, these multivariate models encounter some limitations: the excessive number of parameters that are not easily interpretable; achieving convergence during the estimation process is difficult, especially with the introduction of additional variables; and the lack of ability in measuring the extent of volatility interdependence that is important given the increased level of integrations between markets (Hammoudeh et al., 2009; Arouri et al., 2011, 2015; Sadorsky, 2012). Thus, in order to examine the transmission of volatility between petroleum prices and manually constructed stock sector indices of petroleum exporting and importing countries, this study employs a multivariate GARCH model that consists of two components: (i) the vector autoregressive (VAR) approach; and (ii) the GARCH approach that follows the specification of Ling and McAleer (2003). The model incorporates the constant conditional correlation (CCC) GARCH process of Bollerslev (1990), where the conditional correlations are restricted to be constant through time. The recent empirical studies that have applied such specification of the GARCH model to study volatility transmissions between different markets and demonstrated its efficient performance in volatility modelling include Hammoudeh et al. (2009, 2010), Chang et al. (2010, 2013), Arouri et al. (2011, 2012, 2015), Sadorsky (2012), Salisu and Mobolaji (2013), and Lin et al. (2014). In addition to this fact, it is worth mentioning the advantages of the VAR-GARCH approach over other multivariate models. First, it allows to analyse bidirectional volatility spillover effects between the studied variables. Second, it is not excessive in parameters and enables to estimate meaningful parameters with less computational intricacies.

For each pair of sector and petroleum returns, the study employs the VAR approach to model the conditional mean equation. The optimal number of lags was selected based on the Schwarz Bayesian Criterion (SBC). Although, the SBC criterion chose different lags in each sector and country, for the sake of parsimony, the model with one lag was selected, as based on the preliminary analysis, the model with longer lags showed negligible differences (Appendix, Table A1). Consequently, the conditional mean equation takes the following form:

$$R_{it} = \mu_i + \sum_{j=1}^{n} \phi_{ij} R_{it-1} + \varepsilon_{it} \tag{1}$$

$$\varepsilon_{it} = h_{it}^{1/2} \eta_{it}$$

where, R_{it} denotes the logarithmic returns of *i*th stock sector index and Brent crude petroleum prices at time *t*, ε_{it} refers to error terms, η_{it} is a sequence of *i.i.d.* random errors, and h_{it} is the conditional variance of *i*th stock sector index and Brent petroleum price returns at time *t*.

The conditional variance equation is represented by the GARCH(1,1) process that follows the specification of Ling and McAleer (2003). Chang et al. (2011) suggest that practically multivariate GARCH models with a longer number of lags can cause difficulties during the estimation process. Table A2 in Appendix confirms this and illustrates that in all cases the GARCH(1,1) process fits better based on the SBC criterion. Thus, the conditional variance equation is given as follows:

$$h_{it} = c_{ii} + \sum_{j=1}^{n} \alpha_{ij} \varepsilon_{jt-1}^{2} + \sum_{j=1}^{n} \beta_{ij} h_{jt-1} \tag{2}$$

where, $\sum \alpha_{ij} \varepsilon_{jt-1}^{2}$ is the ARCH term that measures the effects of innovations or shocks, and $\sum \beta_{ij} h_{jt-1}$ is the GARCH term that measures the effects of volatilities. This approach allows past shocks and volatilities of one variable to affect the volatilities of other variables in the system. The second equation shows that the conditional variance of the *i*th stock sector index (or Brent crude petroleum prices) is influenced not only by own past squared errors and variances but also by those of Brent crude petroleum prices (or the *i*th stock sector index), thus capturing spillover effects.

The conditional covariance between *i*th stock sector index and Brent crude petroleum returns is defined as:

$$h_{ijt} = \rho_{ij} h_{iit}^{1/2} h_{jjt}^{1/2} \tag{3}$$

where, ρ_{ij} represents the constant conditional correlation. The considered VAR-GARCH model is estimated by using the quasi-maximum likelihood estimation (QMLE) method since in the case of financial time series, the normality condition does not often hold. The work of Ling and McAleer (2003), which documented in detail the model's necessary conditions, demonstrates that for consistency of the QMLE, the presence of the second moment is sufficient. The results of the estimated model are utilised to construct optimal portfolio weights and hedge ratios.

3. Data description

3.1. Sample selection

To set the sample for the investigation of volatility spillovers between petroleum prices and stock sector indices of petroleum exporters and importers, the study follows several selection procedures. First, petroleum exporting and importing countries are selected based on the annual crude petroleum production and consumption data provided by the British Petroleum Statistical Review of World Energy. The group of petroleum exporters includes countries where the level of petroleum production exceeds petroleum consumption. The group of petroleum importers comprises countries where the level of petroleum consumption surpasses petroleum production. Since the study covers the period from 2005 to 2018, the additional condition, which follows the empirical work of Ramos and Veiga (2013), is that the levels of petroleum production and consumption should remain unchanged during the entire investigation period, i.e. petroleum exporting and importing countries should belong to the same group. The applied criteria contributed to the identification of countries, such as Argentina and Denmark, that fall into both petroleum exporter and importer categories during the estimation period. Given that the level of petroleum production exceeded petroleum consumption during more than 60% of the considered period, it was decided to include Argentina and Denmark to the group of petroleum exporting countries. Second, the final sample of countries is conditional on the maturity of stock markets and availability of data. Thus, in order to avoid liquidity related issues with stock prices, the major stock market indices were chosen. For each of the considered stock market indices, the quarterly constituent lists were extracted from the Eikon and Datastream databases, including official sources of indices, to select sectors and stocks based on the following criteria: (i) sectors of stock market indices should consist of minimum five stocks in each quarter during the whole period of analysis; (ii) stocks should be liquid, particularly in countries with less developed stock markets; and (iii) stock markets should have at least three sectors with five or more stocks. Such restrictions permit to draw conclusions at a sectoral level, not just on several number of stocks, and compare findings among different sectors within both single and multiple countries.

The final sample comprises 7 petroleum exporting countries, namely Argentina, Canada, Denmark, Mexico, Norway, Russia and Saudi Arabia, and 19 petroleum importing countries, namely Australia, Brazil, Chile, China, Eurozone, India, Indonesia, Israel, Japan, New Zealand, Pakistan, South Africa, South Korea, Sweden, Taiwan, Thailand, Turkey, the United Kingdom and United States.[2] The Eurozone consists of 11 member countries, such as Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain, that have started using the euro as their official currency prior to the investigation period. Since the total number of stocks representing each sector in individual countries did not meet the set requirements, it was rational to include them into one group, which allows to keep important petroleum importers and to some extent analyse exposure of equities to the petroleum price risks in the whole European region.

The total number of considered stocks by market and sector are presented in Table 1. The selected market indices do not follow the same industry classification standards. Therefore, the study adopts the Thomson Reuters Business Classification (TRBC), which is regarded as a market-based classification standard, with the purpose of universalisation of the standards. There were 1,105 and 4,663 unique stocks listed from January 2005 to September 2018 in 10 sectors, namely *Basic Materials*, *Consumer Cyclicals*, *Consumer Non-Cyclicals*, *Energy*, *Financials*, *Healthcare*, *Industrials*, *Technology*, *Telecommunications Services* and *Utilities*, of petroleum exporting and importing countries, respectively. The sectors that make up the largest part of the sample are *Basic Materials*, *Energy* and *Financials* in the case of exporters, and *Basic Materials*, *Consumer Cyclicals*, *Financials* and *Industrials* in the case of importers. In total, their shares are approximately 61 percent and 68 percent, respectively. At the individual level, certain markets within petroleum exporters and importers groups are more focused on some sectors. For instance, the *Basic Materials* and *Energy* sectors stand out with the largest number of stocks in Canada, while in the Unites States dominate the *Consumer Cyclicals*, *Financials*, *Industrials* and *Technology* sectors. This indicates that the investigation of volatility spillover effects using aggregate indices could be biased towards certain sectors,

[2] Although countries such as Brazil, China, the United Kingdom and United States are among the largest producers of petroleum, they still had to import this resource to cover local needs during the considered period.

as the weights of sectors vary in petroleum exporting and importing countries depending on their importance. Therefore, the sector level analysis would be rational.

3.2. Data sources

The study employs daily data for the period from January 03, 2005 to September 28, 2018. The sample range is primarily dictated by the objective of focusing on the more recent period to include several global events as the global financial crisis, Arab uprisings, and geopolitical tensions that led to imbalances in the petroleum market, and by the availability of stock market data for important petroleum exporting and importing countries. The US dollar is chosen as the main currency given the fact that grades of crude petroleum are priced and traded in US dollars.

The petroleum market is represented by the Brent grade that is one of the marker sorts and serves as the price barometer for nearly two-thirds of global crude petroleum. The Brent grade is extracted from petroleum fields in the North Sea and easily transported to distant locations. It is classified as sweet and light crude because of low sulphur content and density, which does not require additional refinery costs. Batten et al. (2021) emphasise the appropriateness of the Brent grade for the analysis of hedge ratios between stocks and petroleum, as the other widespread benchmark, West Texas Intermediate (WTI), comprises a local price spread related to petroleum movements at the Cushing (Oklahoma) crude petroleum storage and transportation hub. Their findings suggest that on average the hedging effectiveness is greater when the Brent grade is used compared to the WTI grade. The Brent crude petroleum spot prices were obtained from the Datastream database, where the source of data is the US Energy Information Administration, and are expressed in US dollars. The adjusted closing prices of 5,768 selected stocks, expressed in local currencies, were collected from the Datastream database and converted to US dollars.

3.3. Construction of sector indices and preliminary analysis

The analysis of volatility transmissions at the aggregate level would be quite general as stock sectors in the petroleum exporting and importing countries may have different levels of sensitivity to the petroleum price volatility. Thus, in order to conduct an investigation at the sector level, given the absence of sector indices representing the largest stocks in the majority of countries studied, but particularly in developing, the empirical research adopts a unique approach to self-built sector indices utilising data on individual stocks. First, the major stock market indices presented in Table 1 were considered in the process of choosing sectors and individual stocks. Since the indices do not follow the same industry classification standards, the TRBC was adopted to universalise the standards. Second, the quarterly constituent lists of the aggregate stock market indices were collected for the period from January 2005 to September 2018. Third, several criteria discussed in previous subsections were applied to finalise the list of sectors and stocks for the analysis. Fourth, an equal-weighted approach, which is less biased towards high price and large cap stocks, hence results in greater diversification, was applied to manually construct sector indices for each of the markets, $I_{it} = I_{it-1} \times (1 + r_{it})$, where the base value of sector indices starts from 100, I_{it-1} denotes the value of *i*th sector index at time *t-1*, I_{it} represents the value of *i*th sector index at time *t*, and r_{it} refers to the average of daily logarithmic returns[3] of all stocks listed at time *t*. The stock sector indices were readjusted every quarter during the construction process in order to take into account each joining and leaving firm, and to sustain the continuity of indices. The proposed methodology in this study enables to apply the same approach for the construction of sector indices across 26 analysed markets.

It is worth mentioning some exceptions made in relation to certain markets during the construction process. The number of stocks listed in the *Utilities* sector of India until the 4th quarter of 2006, in the *Basic Materials* and *Utilities* sectors of Russia until the 1st quarters of 2006 and 2007, respectively, and in the *Consumer Cyclicals*, *Consumer Non-Cyclicals* and *Energy* sectors of Saudi Arabia until the 3rd and 1st quarters of 2005 and 2006, respectively, were below the set criteria. Given the importance of these large petroleum importing and exporting countries, the sector indices were built utilising the available stocks to ensure that the starting period of the sample is the same across all markets. In the case of Argentina, all stock sector indices were smoothed on December 17, 2015 due to a devaluation of the local currency by approximately 30 percent[4] associated with the government's decision rather than market factors. In addition, some countries' sectors had stocks with missing values despite the markets being open, which were replaced using linear interpolation.

Table A3 in Appendix reports the results of ARCH and unit root tests.[5] The ARCH effects are present in all series as shown by statistically significant figures of the Engle's test for autoregressive conditional heteroscedasticity of order five, which is applied as a preliminary test for the presence of ARCH effects in residuals, and indicate the suitability of GARCH family models for the investigation of volatility transmissions. The applied Augmented

[3] The daily returns for each of data series are calculated as $ln(P_t/P_{t-1}) \times 100$.
[4] For details see: Reuters, https://www.reuters.com/article/us-argentina-macri-idUSKBN0TZ2ES20151217
[5] For the sake of parsimony, the detailed descriptive statistics, times series graphs of sector indices' values and returns are not presented, but available upon request.

Dickey-Fuller unit root test, where the number of lags were selected using the Schwarz Bayesian Criterion, show that return series are stationary in all cases.

Table 1: Total number of stocks by market and sector listed from January 2005 to September 2018

Country	Index	Basic Materials	Consumer Cyclicals	Consumer Non-Cyclicals	Energy	Financials	Healthcare	Industrials	Technology	Telecommunications Services	Utilities	Total
Panel A: Petroleum Exporters												
Argentina	S&P BYMA	17	-	18	11	14	-	-	-	-	10	70
Canada	S&P TSX	151	44	20	129	74	23	42	28	10	22	543
Denmark	OMXC BENCHMARK	-	18	-	-	46	10	22	-	-	-	96
Mexico	S&P BMV IPC	12	12	14	-	14	-	14	-	-	-	66
Norway	OSE BENCHMARK	-	14	13	36	20	-	29	-	-	-	112
Russia	MOEX	19	-	-	14	-	-	-	-	-	10	43
Saudi Arabia	TADAWUL ALL SHARE	42	18	20	6	67	-	22	-	-	-	175
Total		**241**	**106**	**85**	**196**	**235**	**33**	**129**	**28**	**10**	**42**	**1105**
Panel B: Petroleum Importers												
Australia	S&P ASX 200	102	65	34	51	89	29	59	-	13	11	453
Brazil	IBX	31	21	23	13	53	-	30	-	-	27	198
Chile	S&P IPSA CLP	-	-	13	-	16	-	9	-	-	15	53
China	CSI 300	85	82	38	37	98	37	124	61	-	-	562
Eurozone	MULTIPLE INDICES	75	94	44	28	119	30	105	32	24	34	585
India	S&P BSE 100	23	22	14	15	37	15	18	10	-	9	163
Indonesia	JSX LQ 45	10	-	15	18	20	-	-	-	-	-	63
Israel	TA 125	-	24	11	18	69	-	21	32	-	-	175
Japan	NIKKEI 225	38	38	19	-	30	11	69	26	-	5	236
New Zealand	S&P NZX 50	-	17	-	-	21	-	13	-	-	-	51
Pakistan	KSE 100	33	32	-	12	48	-	-	-	-	12	137
South Africa	FTSE JSE ALL SHARE	53	45	27	-	112	-	34	14	7	-	292
South Korea	KOSPI 200	69	66	43	9	27	32	65	36	-	-	347
Sweden	OMXS 30	-	6	-	-	9	-	10	-	-	-	25
Taiwan	FTSE TW 50	7	-	-	-	16	-	-	29	-	-	52
Thailand	SET 50	-	18	-	13	25	-	15	-	-	-	71
Turkey	BIST 100	34	47	21	-	50	-	30	-	-	-	182
United Kingdom	FTSE 100	27	40	17	12	42	9	33	-	-	12	192
United States	S&P 500	48	138	63	65	145	89	100	119	16	43	826
Total		**635**	**755**	**382**	**291**	**1026**	**252**	**735**	**359**	**60**	**168**	**4663**
Grand Total		**876**	**861**	**467**	**487**	**1261**	**285**	**864**	**387**	**70**	**210**	**5768**

Notes: The Thomson Reuters Business Classification standard is followed. The Eurozone comprises 11 member countries that use the euro as their official currency, namely Austria (ATX), Belgium (BEL 20), Finland (OMXH 25), France (CAC 40), Germany (DAX 30), Greece (ATHEX COMPOSITE), Ireland (ISEQ 20), Italy (FTSE MIB), Netherlands (AEX), Portugal (PSI 20) and Spain (IBEX 35).

4. Empirical results

The discussion of the VAR-GARCH model estimates is partitioned into several subsections. The results of the return spillovers are presented first, followed by the findings of own shock and volatility dependencies as well as interdependencies, and concluded by the outcomes of constant conditional correlations and diagnostic tests.

4.1. Return spillovers

Tables A4 (panels A to G) and A5 (panels A to S) in Appendix report detailed empirical results of the VAR-GARCH model for petroleum and stock sector index pairs of petroleum exporting and importing countries, respectively. The estimated parameters of the mean equation show that interdependence between returns of stock sector indices and petroleum are contingent on the considered sector and market. The current period returns of the majority stock sector indices in petroleum exporting countries, namely Norway and Saudi Arabia, and petroleum importing countries, namely Australia, Indonesia, Japan, New Zealand, South Korea and Taiwan, are affected by one-period lagged petroleum returns as indicated by the significance of corresponding coefficients ($\phi_{1,2}$) at conventional levels, which implies that past petroleum returns can be employed to forecast the direction of sector indices. The statistically significant effects in the reverse course ($\phi_{2,1}$) are more evident for stock sector indices of petroleum exporters, such Mexico and Canada, and petroleum importers, such Brazil, South Africa, the United Kingdom and United States. This finding points to the possibility of utilising returns of sector indices to predict petroleum returns. The estimated own autoregressive parameters of stock sector indices represented by $\phi_{1,1}$ are statistically significant for all markets, except Norway and the United Kingdom, and thus, suggest that past returns of stock sector indices can be efficient in predicting future movements. On the contrary, the results suggest that the current period petroleum returns are not impacted by past values in most cases as shown by the insignificance of $\phi_{2,2}$ coefficients, thereby indicating their weak form of efficiency in forecasting future performance.

4.2. Shock and volatility spillovers

Turning to the variance equations, the parameters $\alpha_{1,1}$ and $\alpha_{2,2}$ represent the past own conditional ARCH effects, which estimate the sensitivity to shocks or short-term persistence, of stock sector indices and petroleum, respectively (Tables A4 and A5 in Appendix). The results display that stock sector indices and petroleum are sensitive to past own shocks or innovations. The estimated coefficients are highly significant in all cases, with the exception of New Zealand and Thailand, where the significance levels vary from 1% to 10%. Among both groups of petroleum exporting and importing countries, the stock sector indices of Argentina have the greatest degree of sensitivity. The past own conditional GARCH effects, which estimate the volatility sensitivity or long-term persistence, of stock sector indices and petroleum are represented by parameters $\beta_{1,1}$ and $\beta_{2,2}$, respectively (Tables A4 and A5 in Appendix). The conditional volatility of all stock sector indices and petroleum are positively influenced by past own volatility as shown by the significance of coefficients at the 1% level. The magnitude of sensitivity differs across sectors and countries, but appears to be higher for stock sector indices of China. The estimated coefficients of own ARCH terms are relatively smaller in size compared to the coefficients of own GARCH terms for all studied series. This finding suggests that stock sector indices and petroleum are generally more impacted by fundamental factors rather than news, and the conditional volatility exhibits more gradual swings over time rather than rapid reactions to shocks or innovations.

Table 2 (panels A and B) summarises shock or innovation and volatility transmissions between petroleum and stock sector indices of seven petroleum exporting countries. The empirical results provide no evidence of shock and volatility interdependencies between petroleum and all stock sector indices of Denmark, and unexpectedly, Saudi Arabia. Wang and Liu (2016) also do not report volatility spillovers between the petroleum market and the stock market of Saudi Arabia, although the authors consider the aggregate market index. The absence of cross effects for Saudi Arabia could be elucidated by several reasons such as local regulations related to the ownership of listed companies by investors from the Gulf Cooperation Council countries up to 25% and by foreign investors through legal entities only (Arouri et al., 2011a), which were eased after 2019, and non-market factors as geopolitical events that tend to frequently influence markets in the Middle East (Wang and Liu, 2016). In the case of Denmark, the country's lower level of petroleum production compared to other large exporters and the increased production, including consumption, of renewable energy over the past decades[6] could provide a plausible explanation for the obtained results.

It is interesting to note that past shocks or innovations emanating from all stock sector indices of Mexico, Canada, except the *Consumer Cyclicals* sector, and the *Basic Materials* and *Energy* sectors of Russia significantly affect the conditional volatility of petroleum, thereby

[6] For details see: Danish EA, https://ens.dk/sites/ens.dk/files/Statistik/energystatistics2019_webtilg.pdf

emphasising the importance of news arising from the sectors of these largest petroleum exporting countries for the petroleum market. The effects in the reverse direction were detected only for the *Utilities* sectors of Argentina and Canada, and the *Consumer Cyclicals* and *Financials* sectors of Norway. The findings provide evidence of volatility transmissions from petroleum to stock sector indices. More specifically, the past volatility of petroleum spills over to the *Utilities* sector of Argentina, the *Financials*, *Healthcare* and *Industrials* sector of Canada, the *Consumer Cyclicals* and *Consumer Non-Cyclicals* sectors of Mexico, and the *Consumer Cyclicals* and *Financials* sectors of Norway. Inversely, it was observed that the past volatility of the *Financials*, *Industrials* and *Technology* sectors of Canada, the *Basic Materials*, *Consumer Non-Cyclicals* and *Financials* sectors of Mexico, the *Consumer Cyclicals* sector of Norway, and the *Basic Materials* sector of Russia, impact the conditional volatility of petroleum, but negatively as indicated by signs of corresponding coefficients (Table A4 in Appendix). This result suggests that sector indices' volatility cools off petroleum volatility in the long run, possibly because of the efficient performance of companies within these sectors, which potentially might signal less stagnant periods in the economies of large petroleum exporting countries as Canada, Mexico, Norway and Russia. Some empirical studies obtained a similar finding for the large petroleum exporting countries, that is, the significant volatility transmissions from the aggregate stock markets to the petroleum market were documented (Malik and Hammoudeh, 2007; Lin et al., 2014; Belhassine and Karamti, 2021; among others). The negative conditional volatility interdependency is present only between the *Consumer Cyclicals* sector of Norway and petroleum, implying that their past volatility offsets the current volatility of each other.

Table 3 (panels A to D) provides a summary of shock or innovation and volatility spillovers between petroleum and stock sector indices of nineteen petroleum importing nations. A particular attention should be given to important petroleum importing countries presented in panel A that are among the largest producers of petroleum, but whose production levels do not allow to meet local needs. Starting with China and the United Kingdom, no evidence of bilateral transmissions of shocks or innovations and volatility was found between petroleum and majority of stock sector indices. While such result is foreseeable for some sectors of the United Kingdom, the absence of interdependencies for the *Basic Materials*, *Industrials* and *Financials* sectors is to a certain degree unexpected and could be attributed to the effectiveness of strategies employed by companies within these sectors to mitigate risks originating from petroleum prices. For the *Energy* and *Utilities* sectors, it was detected that past shocks or innovations of sector indices impact the conditional volatility of petroleum. However, in the opposite direction, only volatility from petroleum transmits to the *Utilities* sector. The shock or innovation and volatility interactions between petroleum and stock sector indices of China, the second largest petroleum consumer in the world, are rather limited. This outcome is partially consistent with works of Yousaf and Hassan (2019), Ashfaq et al. (2019) and Sarwar et al. (2019) that do not report significant volatility spillovers between the Chinese stock market and petroleum. The latter two studies suggest that regulations imposed by the government with respect to the ownership caps for foreign investors may potentially act as a shield from petroleum price shocks. It is worth noting that the conditional volatility of the *Consumer Cyclicals*, *Financials* and *Technology* sectors is affected by the past volatility of petroleum, although negatively, but with low magnitude, as shown by the coefficients' signs (Table A5 in Appendix). This observation appears to indicate that periods of relative stability in the petroleum market are associated with a decline of volatility in three sectors.

The empirical findings depict that volatility spillover effects are more evident between petroleum and stock sector indices of Brazil and the United States. Shocks or innovations originated from all considered sectors of both countries, except the *Telecommunications Services* sector of the United States, significantly affect the conditional volatility of petroleum, and thus, point to the capability of unforeseen events and news in these markets to cause increased volatility in the petroleum market. The transmissions from petroleum to stock sector indices are present only for the *Consumer Non-Cyclicals* sector of Brazil, and the *Basic Materials*, *Industrials* and *Technology* sectors of the United States. In terms of cross volatility spillovers, it was observed that the past volatility of only the *Energy* and *Utilities* sectors of Brazil influence the conditional volatility of petroleum. While for the United States, the past volatility of most sector indices is important in explaining the conditional volatility of petroleum. However, one can note that the corresponding coefficients have negative signs as in the case with petroleum exporting countries (Table A5 in Appendix). Hence, the rationale provided in the earlier paragraph also holds for stock sector indices of Brazil and the United States. Interestingly, the effects in the contrary direction were not observed. The documented results are in line, albeit partially, with studies of Malik and Ewing (2009), Arouri et al. (2011b), and Salisu and Oloko (2015) that focus on the United States.

Looking across other petroleum importing countries presented in panels B to D of Table 3, the volatility spillover effects are country- and sector-specific. There is no evidence indicating the presence of shock or innovation and volatility transmissions between petroleum and stock sector indices of developing markets as Chile, India, Indonesia, and Thailand. Wang and Liu (2016) and Ashfaq et al. (2019) also do not observe statistically significant effects for India. On the other hand, Yousaf and Hassan (2019) found some evidence of volatility interactions between petroleum and aggregate market indices of India and Indonesia, but not of Thailand, during the full sample period. The obtained findings suggest that considered stock sectors are not sensitive at the individual level possibly due to the low integration with the world's petroleum market. In the case of New Zealand and Sweden, the absence of volatility spillovers between petroleum and stock sector indices of developed markets could be explained by a relatively large consumption of energy from renewable sources, which appears to make them immune to the petroleum price volatility. Some evidence was obtained for South Africa, Taiwan and Turkey. Specifically, shocks or innovations spill over from the *Basic Materials* and *Technology* sectors of Taiwan to petroleum, while the opposite effects from petroleum to the *Consumer Non-Cyclicals* and *Industrials* sectors of Turkey were detected. In the case of South Africa, only the past volatility of petroleum impacts the conditional volatility of the *Technology* sector. Yousaf and Hassan (2019) report statistically significant results for Taiwan, and Vardar et al. (2018) for Turkey and South Africa.

The shocks or innovations originating from petroleum were found to significantly influence the conditional volatility of the *Consumer Cyclicals*, *Consumer Non-Cyclicals*, *Financials*, *Healthcare* and *Industrials* sectors of Australia, the *Industrials* and *Technology* sectors of the Eurozone, the *Basic Materials*, *Consumer Cyclicals*, *Healthcare*, *Industrials*, *Technology* and *Utilities* sectors of Japan, the *Energy* and *Financial* sectors of Pakistan, and the *Basic Materials* and *Consumer-Cyclicals* sectors of South Korea. The spillover effects in the inverse route were detected for the *Telecommunications Services* sector of the Eurozone, the *Consumer Cyclicals*, *Consumer Non-Cyclicals*, *Energy* and *Financials* sectors of Israel, the *Consumer Non-Cyclicals* sector of Japan, and the *Financials* and *Industrials* sectors of South Korea. In addition, bidirectional transmissions of shocks or innovations between petroleum and stock sector indices were documented for the *Energy* sector of Australia, the *Industrials* sector of Israel, the *Basic Materials* and *Consumer Cyclicals* sectors of Pakistan, and the *Healthcare* and *Technology* sectors of South Korea. The findings provide less evidence with regard to conditional volatility interdependencies. The past volatility of petroleum spills over to the *Consumer Non-Cyclicals* and *Industrials* sectors of Australia, *Consumer Cyclicals* and *Industrials* sectors of the Eurozone, the *Energy* and *Financials* sectors of Pakistan, and the *Utilities* sector of Japan, whilst the past volatility of the *Telecommunications* sector of the

Eurozone, and the *Consumer Non-Cyclicals*, *Energy*, *Financials* and *Industrials* sectors of Israel impact the conditional volatility of petroleum. The two-way volatility transmissions were observed only between petroleum and the *Basic Materials* and *Consumer Cyclicals* sectors of Pakistan, where the level of petroleum dependency remains high. However, it is necessary to underline that all coefficients of volatility interactions have negative signs (Table A5 in Appendix). The results are moderately consistent with researches of Arouri et al. (2012), Sarwar et al. (2019), Sarwar et al. (2020), Yousaf and Hassan (2019) and Belhassine (2020). In the case of Israel, as one can note, shock and volatility spillovers are surprisingly unidirectional from most sector indices to petroleum. The stock market of Israel is strongly integrated with the world's financial and commodity markets. The large share of petroleum in the primary energy consumption[7] and location in the petroleum rich region with frequent instabilities that the country's stock market might be exposed to could elucidate the obtained findings.

To summarise, the extensive evidence of significant shock and volatility transmissions between petroleum and stock sector indices of petroleum exporting and importing countries were obtained. The direction and magnitude of spillover effects depend on the considered markets and sectors. However, it is interesting to observe that transmissions generally occur from stock sector indices to petroleum in the case of petroleum exporters and from petroleum to stock sector indices of petroleum importers, excluding countries that have large production levels. In the group of petroleum exporting countries, the volatility cross effects are more apparent for sector indices of Canada and Mexico. Among petroleum importing countries, the volatility interactions were detected more for sector indices of Brazil, the United States, Australia, Israel, Japan, Pakistan and South Korea. Table 4 reports the total number of shock and volatility transmissions, both bilateral and unilateral, which considerably vary across sectors of petroleum exporters and importers. The observed shock and volatility spillovers are greater in the *Basic Materials* and *Financials* sectors of petroleum exporters, and for most sectors of petroleum importers. By contrast, the amount of documented interdependencies is small in the *Telecommunications Services* sector of both country groups and the *Healthcare* sector of petroleum importers. Overall, the findings reveal that past shocks or innovations arising from sector indices (or petroleum) compared to past volatilities play a more prominent role in comprehending the conditional volatility of petroleum (or sector indices).

[7] BP Statistical Review of World Energy 2018.

4.3. Constant conditional correlations

The estimated constant conditional correlations, represented by ($\rho_{2,1}$), between petroleum and stock sector indices of petroleum exporting and importing countries are positive and statistically significant at conventional levels in all cases, except the *Utilities* sector of Japan (Tables A4 and A5 in Appendix). In the case of petroleum exporters, as expected, the strongest conditional correlations were observed between petroleum and the *Energy* sectors of Russia (0.4360), Norway (0.4945) and Canada (0.4972), while the lowest between petroleum and the *Consumer Non-Cyclicals* (0.1023), *Consumer Cyclicals* (0.1047) and *Financials* (0.1051) sectors of Saudi Arabia. In the group of petroleum importers, the *Energy* sectors of the United States (0.4304), Eurozone (0.4738) and United Kingdom (0.4907) also have high conditional correlations with petroleum, whereas the *Consumer Non-Cyclicals* (0.0691) and *Healthcare* (0.0510) sectors of China, the *Basic Materials* (0.0320), *Financials* (0.0343) and *Utilities* (0.0390) sectors of Pakistan, and *Consumer Non-Cyclicals* (0.0584) and *Healthcare* (0.0577) sectors of Japan have the smallest conditional correlations with petroleum. The sector indices of petroleum exporters on average have stronger correlations than those of petroleum importers. The weak constant conditional correlations may be a tempting indicator for potential gains from holding both stock sector index and petroleum assets in one portfolio. However, Arouri et al. (2012) suggest that shock and volatility transmissions should be considered by portfolio managers when identifying optimal portfolio weights and hedging ratios in order to properly manage petroleum risks.

4.4. Diagnostics

The necessary and sufficient condition for consistency of the QMLE for the considered GARCH model is the existence of the second moment, where $\alpha + \beta < 1$.[8] Tables A4 and A5 in Appendix show that second moment conditions for stock sector index and petroleum pairs, presented as $\alpha_{1,1} + \beta_{1,1}$ and $\alpha_{2,2} + \beta_{2,2}$, respectively, are less than one in all cases. In addition, a set of diagnostic tests were applied for standardised residuals and squared standardised residuals in order to check the adequacy of VAR-GARCH models for all pairs. Overall, the results indicate that serial correlations are mostly absent at 1% significance level (Tables A4 and A5 in Appendix). However, it is worth noting that diagnostic tests show some evidence of

[8] Refer to the work of Ling and McAleer (2003) for more details on necessary conditions.

autocorrelations in certain cases, albeit the computed values are negligible. Thus, it can be concluded that the estimated models were correctly specified and captured all properties.

Table 2: Summary of shock and volatility transmissions between petroleum and stock sector indices of petroleum exporting countries.

Panel A	Argentina		Canada		Denmark		Mexico	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	0	0	S → P	0	-	-	S → P	S → P
Consumer Cyclicals	-	-	0	0	0	0	S → P	S ← P
Consumer Non-Cyclicals	0	0	S → P	0	-	-	S → P	S ↔ P
Energy	0	0	S → P	0	-	-	-	-
Financials	0	0	S → P	S ↔ P	0	0	S → P	S → P
Healthcare	-	-	S → P	S ← P	0	0	-	-
Industrials	-	-	S → P	S ↔ P	0	0	S → P	0
Technology	-	-	S → P	S → P	-	-	-	-
Telecommunications Services	-	-	S → P	0	-	-	-	-
Utilities	S ← P	S ← P	S ↔ P	0	-	-	-	-

Panel B	Norway		Russia		Saudi Arabia	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	-	-	S → P	S → P	0	0
Consumer Cyclicals	S ← P	S ↔ P	-	-	0	0
Consumer Non-Cyclicals	0	0	-	-	0	0
Energy	0	0	S → P	0	0	0
Financials	S ← P	S ← P	-	-	0	0
Healthcare	-	-	-	-	-	-
Industrials	0	0	-	-	0	0
Technology	-	-	-	-	-	-
Telecommunications Services	-	-	-	-	-	-
Utilities	-	-	0	0	-	-

Notes: S and P denote stock sector indices and petroleum, respectively. The ARCH term represents innovation or shock spillovers and the GARCH term represents volatility spillovers. The arrows → (←) indicate the direction of innovation or shock and volatility spillovers from stock sector indices to petroleum (from petroleum to stock sector indices), ↔ captures bidirectional spillovers, and 0 refers to the absence of innovation or shock and volatility spillovers between the studied pairs.

Table 3: Summary of shock and volatility transmissions between petroleum and stock sector indices of petroleum importing countries.

Panel A	Brazil		China		United Kingdom		United States	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	S → P	0	0	0	0	0	S ↔ P	S → P
Consumer Cyclicals	S → P	0	0	S ← P	0	0	S → P	S → P
Consumer Non-Cyclicals	S ↔ P	0	0	0	0	0	S → P	S → P
Energy	S → P	S → P	0	0	S → P	0	S → P	0
Financials	S → P	0	0	S ← P	0	0	S → P	S → P
Healthcare	-	-	0	0	0	0	S → P	S → P
Industrials	S → P	0	0	0	0	0	S ↔ P	S → P
Technology	-	-	0	S ← P	-	-	S ↔ P	S → P
Telecommunications Services	-	-	-	-	-	-	0	0
Utilities	S → P	S → P	-	-	S → P	S ← P	S → P	0

Panel B	Australia		Chile		Eurozone		India		Indonesia	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	0	0	-	-	0	0	0	0	0	0
Consumer Cyclicals	S ← P	0	-	-	0	S ← P	0	0	-	-
Consumer Non-Cyclicals	S ← P	S ← P	0	0	0	0	0	0	0	0
Energy	S ↔ P	0	-	-	0	0	0	0	0	0
Financials	S ← P	0	0	0	0	0	0	0	0	0
Healthcare	S ← P	0	-	-	0	0	0	0	-	-
Industrials	S ← P	S ← P	0	0	S ← P	S ← P	0	0	-	-
Technology	-	-	-	-	S ← P	0	0	0	-	-
Telecommunications Services	0	0	-	-	S → P	S → P	-	-	-	-
Utilities	0	0	0	0	0	0	0	0	-	-

Panel C	Israel		Japan		New Zealand		Pakistan		South Africa	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	-	-	S ← P	0	-	-	S ↔ P	S ↔ P	0	0
Consumer Cyclicals	S → P	0	S ← P	0	0	0	S ↔ P	S ↔ P	0	0
Consumer Non-Cyclicals	S → P	S → P	S → P	0	-	-	-	-	0	0
Energy	S → P	S → P	-	-	-	-	S ← P	S ← P	-	-
Financials	S → P	S → P	0	0	0	0	S ← P	S ← P	0	0
Healthcare	-	-	S ← P	0	-	-	-	-	-	-
Industrials	S ↔ P	S → P	S ← P	0	0	0	-	-	0	0
Technology	0	0	S ← P	0	-	-	-	-	0	S ← P
Telecommunications Services	-	-	-	-	-	-	-	-	0	0
Utilities	-	-	S ← P	S ← P	-	-	0	0	-	-

Panel D	South Korea		Sweden		Taiwan		Thailand		Turkey	
	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH	ARCH	GARCH
Basic Materials	S ← P	0	-	-	S → P	0	-	-	0	0
Consumer Cyclicals	0	0	0	0	-	-	0	0	0	0
Consumer Non-Cyclicals	S ← P	0	-	-	-	-	-	-	S ← P	0
Energy	0	0	-	-	-	-	0	0	-	-
Financials	S → P	0	0	0	0	0	0	0	0	0
Healthcare	S ↔ P	0	-	-	-	-	-	-	-	-
Industrials	S → P	0	0	0	-	-	0	0	S ← P	0
Technology	S ↔ P	0	-	-	S → P	0	-	-	-	-
Telecommunications Services	-	-	-	-	-	-	-	-	-	-
Utilities	-	-	-	-	-	-	-	-	-	-

Notes: S and P denote stock sector indices and petroleum, respectively. The ARCH term represents innovation or shock spillovers and the GARCH term represents volatility spillovers. The arrows → (←) indicate the direction of innovation or shock and volatility spillovers from stock sector indices to petroleum (from petroleum to stock sector indices), ↔ captures bidirectional spillovers, and 0 refers to the absence of innovation or shock and volatility spillovers between the studied pairs.

Table 4: Total number of shock and volatility transmissions, both unidirectional and bidirectional, between petroleum and stock sector indices of petroleum exporting and importing countries.

Sectors	Exporters			Importers		
	№ of Countries	№ of ARCH	№ of GARCH	№ of Countries	№ of ARCH	№ of GARCH
Basic Materials	5	3	2	14	6	2
Consumer Cyclicals	5	2	2	16	6	4
Consumer Non-Cyclicals	5	2	1	14	7	3
Energy	5	2	0	12	6	3
Financials	6	3	3	19	6	4
Healthcare	2	1	1	8	4	1
Industrials	5	2	1	16	8	4
Technology	1	1	1	9	5	3
Telecommunications Services	1	1	0	4	1	1
Utilities	3	2	1	9	4	3

Notes: The ARCH and GARCH terms represent innovation or shock and volatility spillovers, respectively.

5. Optimal portfolio weights and hedge ratios

Given the considerable shock and volatility spillovers between petroleum and stock sector indices of petroleum exporters and importers, the present study demonstrates the process of managing efficiently risks associated with petroleum price swings by quantifying optimal portfolio weights and hedge ratios based on the conditional volatility estimates of the VAR-GARCH models for each stock sector index and petroleum pairs.

First, optimal weights of holding two assets, specifically a stock sector index and petroleum, in an investment portfolio, where a short-selling strategy is restricted, that aims to minimise risks without decreasing expected returns are constructed applying the methodology of Kroner and Ng (1998):

$$w_{ij,t} = \frac{h_{jj,t} - h_{ij,t}}{h_{ii,t} - 2h_{ij,t} + h_{jj,t}} \quad (4)$$

and

$$w_{ij,t} = \begin{cases} 0, & if\ w_{ij,t} < 0 \\ w_{ij,t}, & if\ 0 \leq w_{ij,t} \leq 1 \\ 1, & if\ w_{ij,t} > 1 \end{cases} \quad (5)$$

where, $w_{ij,t}$ represents the first asset's weight in a one-dollar portfolio consisting of a stock sector index and petroleum at time *t*, $h_{ii,t}$ and $h_{jj,t}$ are the conditional variances of assets *i* and *j* at time *t*, respectively, and $h_{ij,t}$ refers to the conditional covariance between two considered assets at time *t*. Hence, the second asset's weight in a portfolio is derived as $1 - w_{ij,t}$.

Second, in order to reduce risks of a portfolio comprising a stock sector index and petroleum, the hedge ratios between assets *i* and *j* are computed following the approach of Kroner and Sultan (1993), which is one of the most widely utilised methods, as:

$$\beta_{ij,t} = \frac{h_{ij,t}}{h_{jj,t}} \quad (6)$$

In the above equation, a risk-minimising hedge ratio at time *t* is denoted as $\beta_{ij,t}$, that is, a one-dollar ($1) long position taken in one asset should be hedged by a short position equivalent to $\$\beta_{ij,t}$ in the second asset at time *t*. Thus, it is important to note that hedging is considered effective if the obtained hedge ratios are low or inexpensive (Hammoudeh et al., 2010).

The average figures of optimal portfolio weights and hedge ratios related to petroleum exporting and importing countries are reported in Table 5 (panels A and B) and Table 6 (panels

A to D). The findings indicate that optimal portfolio weights considerably vary among markets and sectors. Turning out to petroleum exporters first, for instance, the average weight for the *Financials/Petroleum* portfolio of Canada is 0.883, which is the highest value compared to other markets, suggesting that in a $1 portfolio, 88.3 cents should be invested in the *Financials* sector index and the remaining amount of 11.7 cents in petroleum. The smallest weight is detected for Argentina, where the optimal holding of the *Financials* sector index in a $1 portfolio is 53.2 cents, with the outstanding amount of 46.8 cents to be invested in petroleum. It can be noted that weights of petroleum exceed those of sector indices in the *Basic Materials/Petroleum* and *Utilities/Petroleum* portfolios of Russia, and the *Basic Materials/Petroleum* portfolio of Canada. On average, optimal holdings of petroleum in portfolios are lower for Canada and higher for Russia, implying that risks associated with petroleum prices are greater for the former than for the latter petroleum exporting country.

In the case of petroleum importing countries, the average weights for the *Financials/Petroleum* portfolios range from 0.430 for Brazil to 0.824 for New Zealand. These figures suggest that in the case of Brazil, the amount of funds allocated in a $1 portfolio to the *Financials* sector index and petroleum should be 43.0 cents and 57.0 cents, respectively. For New Zealand, in a $1 portfolio, the optimal investment in the *Financials* sector index is 82.4 cents, while the remainder of 17.6 cents should be assigned to petroleum. The highest weight of a sector index was found in the *Consumer Non-Cyclicals/Petroleum* portfolio of the United States, which equals to 0.864. On the other hand, investors should own more petroleum than a stock sector index in the *Basic Materials/Petroleum*, *Consumer Cyclicals/Petroleum*, *Energy/Petroleum* and *Financials/Petroleum* portfolios of Brazil, the *Basic Materials/Petroleum*, *Consumer Cyclicals/Petroleum*, *Financials/Petroleum* and *Industrials/Petroleum* portfolios of Turkey, the *Basic Materials/Petroleum*, *Energy/Petroleum* and *Technology/Petroleum* portfolios of China, the *Basic Materials/Petroleum* and *Energy/Petroleum* portfolios of Indonesia, the *Energy/Petroleum* portfolio of Australia, and the *Financials/Petroleum* portfolio of India. Interestingly, the results indicate that average optimal holdings of petroleum are greater in portfolios that include sector indices of developing markets, namely Brazil, China, India, Indonesia and Turkey, which implies that risks arising from petroleum prices are lower for these markets than for their developed counterparts. Overall, one can observe that portfolios should consist of more sector indices and less petroleum, excluding some sectors of petroleum exporters and importers where the opposite trends are recorded, in order to minimise risks without decreasing expected returns.

The average values of the hedge ratios show substantial variability from one sector to another. Starting with petroleum exporting countries, for example, the average value between petroleum and the *Financials* sector index of Canada is 0.709, implying that a long position of $1 in a petroleum asset can be hedged with a short position of 70.9 cents in the *Financials* sector index. However, the average figure of the optimal hedge ratio between the same assets is much lower for Saudi Arabia, suggesting that a $l long position in petroleum should be shorted by approximately 13.9 cents of the *Financial* sector index. It can be noted that the most efficient strategy to hedge petroleum risks is to take a short position in the *Consumer Non-Cyclicals* sector index of Saudi Arabia and the least efficient is to use the *Financials* sector index of Canada. In general, the sector indices of Saudi Arabia provide lower costs of hedging exposure to petroleum risks, while the hedging costs are the most expensive in the case of Canada. This outcome is in line with the study of Arouri et al. (2011a) that reports low hedge ratios for Saudi Arabia. Among sector indices of all petroleum exporting countries, the smallest hedge ratios are between the *Consumer Cyclicals* and *Financials* sector indices of Saudi Arabia and petroleum, where long positions of $1 in sector indices can be hedged by short positions of less than 10 cents in the latter.

A glance at petroleum importing countries illustrates that the optimal hedge ratios between petroleum and the *Financials* sectors vary from 0.454 for Chile to 0.061 for Pakistan, suggesting that a long position of $1 in a petroleum asset should be hedged with short positions of 45.4 cents and 6.1 cents in the *Financials* sector index of the first and second countries, respectively. The results indicate that it is not desirable to hedge a $1 long position in petroleum with short positions in the *Energy* sector indices of the Eurozone and United Kingdom as the associated costs are high. On the contrary, the smallest hedge ratio was obtained between petroleum and the *Utilities* sector of Japan. More specifically, a $1 investment in petroleum should be shorted by 2.4 cents in the stock sector index to minimise risks. Among petroleum importers, the best hedging opportunities are provided by sector indices of China and Pakistan, whereas the greater costs associated with hedging petroleum risk exposure are offered by sector indices of the Eurozone and United Kingdom. In addition, it is worth mentioning that on average the hedge ratios are also small for India, Indonesia, Japan, South Korea and Turkey. These findings are moderately consistent with those of Yousaf and Hassan (2019), and Belhassine and Karamti (2021), although the authors use different methodologies and aggregate market indices. Comparing sectors, it can be noted that the lowest optimal hedge ratio is between the *Utilities* sector index of Japan and petroleum, where a $l long position in the sector index should be hedged with a short position of only 1.3 cents in petroleum.

To conclude, the results support the argument that the risk-adjusted performance of a diversified portfolio of sector indices is improved by the inclusion of a petroleum asset (Arouri et al., 2012). The obtained optimal portfolio weights and hedge ratios differ substantially, thereby confirming heterogeneity of sectors within the petroleum exporting and importing countries. It appears that the sector indices of Saudi Arabia and China provide lower hedging costs, reflecting their efficiency in hedging exposure to petroleum price risks.

Table 5: Average optimal portfolio weights and hedge ratios for petroleum exporting countries.

Panel A	Argentina		Canada		Denmark		Mexico	
	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	0.623	0.132	0.470	0.361	-	-	0.577	0.257
Petroleum/Basic Materials	0.377	0.209	0.530	0.326	-	-	0.423	0.327
Consumer Cyclicals/Petroleum	-	-	0.845	0.178	0.740	0.151	0.654	0.185
Petroleum/Consumer Cyclicals	-	-	0.155	0.590	0.260	0.363	0.346	0.313
Consumer Non-Cyclicals/Petroleum	0.671	0.132	0.872	0.142	-	-	0.705	0.167
Petroleum/Consumer Non-Cyclicals	0.329	0.258	0.128	0.570	-	-	0.295	0.345
Energy/Petroleum	0.575	0.267	0.583	0.462	-	-	-	-
Petroleum/Energy	0.425	0.332	0.417	0.550	-	-	-	-
Financials/Petroleum	0.532	0.145	0.883	0.182	0.756	0.174	0.607	0.203
Petroleum/Financials	0.468	0.158	0.117	0.709	0.244	0.461	0.393	0.292
Healthcare/Petroleum	-	-	0.650	0.175	0.698	0.169	-	-
Petroleum/Healthcare	-	-	0.350	0.295	0.302	0.343	-	-
Industrials/Petroleum	-	-	0.840	0.199	0.666	0.237	0.618	0.196
Petroleum/Industrials	-	-	0.160	0.610	0.334	0.424	0.382	0.290
Technology/Petroleum	-	-	0.744	0.167	-	-	-	-
Petroleum/Technology	-	-	0.256	0.391	-	-	-	-
Telecommunications Services/Petroleum	-	-	0.840	0.149	-	-	-	-
Petroleum/Telecommunications Services	-	-	0.160	0.514	-	-	-	-
Utilities/Petroleum	0.523	0.136	0.858	0.196	-	-	-	-
Petroleum/Utilities	0.477	0.136	0.142	0.642	-	-	-	-

Panel B	Norway		Russia		Saudi Arabia	
	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	-	-	0.496	0.393	0.671	0.126
Petroleum/Basic Materials	-	-	0.504	0.392	0.329	0.242
Consumer Cyclicals/Petroleum	0.627	0.268	-	-	0.636	0.089
Petroleum/Consumer Cyclicals	0.373	0.408	-	-	0.364	0.151
Consumer Non-Cyclicals/Petroleum	0.552	0.283	-	-	0.569	0.103
Petroleum/Consumer Non-Cyclicals	0.448	0.331	-	-	0.431	0.130
Energy/Petroleum	0.367	0.588	0.510	0.452	0.577	0.129
Petroleum/Energy	0.633	0.434	0.490	0.461	0.423	0.171
Financials/Petroleum	0.616	0.315	-	-	0.618	0.088
Petroleum/Financials	0.384	0.452	-	-	0.382	0.139
Healthcare/Petroleum	-	-	-	-	-	-
Petroleum/Healthcare	-	-	-	-	-	-
Industrials/Petroleum	0.647	0.306	-	-	0.585	0.119
Petroleum/Industrials	0.353	0.480	-	-	0.415	0.160
Technology/Petroleum	-	-	-	-	-	-
Petroleum/Technology	-	-	-	-	-	-
Telecommunications Services/Petroleum	-	-	-	-	-	-
Petroleum/Telecommunications Services	-	-	-	-	-	-
Utilities/Petroleum	-	-	0.411	0.384	-	-
Petroleum/Utilities	-	-	0.589	0.273	-	-

Notes: Petroleum is represented by the Brent grade. w and β denote average weights and hedge ratios (long/short), respectively, of assets in the portfolio comprising a stock sector index and petroleum.

Table 6: Average optimal portfolio weights and hedge ratios for petroleum importing countries.

Panel A	Brazil		China		United Kingdom		United States	
	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	0.420	0.300	0.496	0.111	0.502	0.408	0.717	0.165
Petroleum/Basic Materials	0.580	0.231	0.504	0.110	0.498	0.411	0.283	0.365
Consumer Cyclicals/Petroleum	0.447	0.263	0.542	0.080	0.704	0.172	0.745	0.081
Petroleum/Consumer Cyclicals	0.553	0.219	0.458	0.097	0.296	0.369	0.255	0.232
Consumer Non-Cyclicals/Petroleum	0.523	0.230	0.562	0.065	0.808	0.131	0.864	0.039
Petroleum/Consumer Non-Cyclicals	0.477	0.247	0.438	0.085	0.192	0.428	0.136	0.239
Energy/Petroleum	0.387	0.376	0.471	0.135	0.688	0.405	0.574	0.401
Petroleum/Energy	0.613	0.260	0.529	0.122	0.312	0.632	0.426	0.479
Financials/Petroleum	0.430	0.260	0.519	0.074	0.656	0.223	0.713	0.110
Petroleum/Financials	0.570	0.204	0.481	0.082	0.344	0.391	0.287	0.282
Healthcare/Petroleum	-	-	0.559	0.048	0.773	0.131	0.815	0.049
Petroleum/Healthcare	-	-	0.441	0.064	0.227	0.361	0.185	0.207
Industrials/Petroleum	0.507	0.227	0.546	0.078	0.737	0.177	0.776	0.106
Petroleum/Industrials	0.493	0.230	0.454	0.095	0.263	0.413	0.224	0.331
Technology/Petroleum	-	-	0.497	0.078	-	-	0.734	0.096
Petroleum/Technology	-	-	0.503	0.078	-	-	0.266	0.248
Telecommunications Services/Petroleum	-	-	-	-	-	-	0.697	0.094
Petroleum/Telecommunications Services	-	-	-	-	-	-	0.303	0.211
Utilities/Petroleum	0.503	0.209	-	-	0.762	0.140	0.811	0.059
Petroleum/Utilities	0.497	0.211	-	-	0.238	0.358	0.189	0.235

Panel B	Australia		Chile		Eurozone		India		Indonesia	
	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	0.535	0.259	-	-	0.709	0.241	0.560	0.165	0.499	0.162
Petroleum/Basic Materials	0.465	0.287	-	-	0.291	0.498	0.440	0.205	0.501	0.159
Consumer Cyclicals/Petroleum	0.716	0.182	-	-	0.725	0.202	0.622	0.125	-	-
Petroleum/Consumer Cyclicals	0.284	0.387	-	-	0.275	0.470	0.378	0.200	-	-
Consumer Non-Cyclicals/Petroleum	0.717	0.168	0.737	0.151	0.812	0.150	0.671	0.120	0.575	0.148
Petroleum/Consumer Non-Cyclicals	0.283	0.360	0.263	0.373	0.188	0.511	0.329	0.234	0.425	0.194
Energy/Petroleum	0.498	0.319	-	-	0.746	0.360	0.560	0.119	0.463	0.209
Petroleum/Energy	0.502	0.315	-	-	0.254	0.683	0.440	0.148	0.537	0.179
Financials/Petroleum	0.710	0.176	0.787	0.148	0.622	0.227	0.486	0.166	0.553	0.138
Petroleum/Financials	0.290	0.376	0.213	0.454	0.378	0.362	0.514	0.153	0.447	0.165
Healthcare/Petroleum	0.711	0.166	-	-	0.756	0.158	0.663	0.119	-	-
Petroleum/Healthcare	0.289	0.346	-	-	0.244	0.408	0.337	0.223	-	-
Industrials/Petroleum	0.663	0.203	0.678	0.161	0.711	0.208	0.515	0.161	-	-
Petroleum/Industrials	0.337	0.357	0.322	0.311	0.289	0.455	0.485	0.165	-	-
Technology/Petroleum	-	-	-	-	0.682	0.196	0.606	0.120	-	-
Petroleum/Technology	-	-	-	-	0.318	0.381	0.394	0.183	-	-
Telecommunications Services/Petroleum	0.687	0.163	-	-	0.749	0.176	-	-	-	-
Petroleum/Telecommunications Services	0.313	0.314	-	-	0.251	0.439	-	-	-	-
Utilities/Petroleum	0.696	0.187	0.786	0.132	0.740	0.185	0.541	0.145	-	-
Petroleum/Utilities	0.304	0.368	0.214	0.404	0.260	0.445	0.459	0.166	-	-

Panel C	Israel		Japan		New Zealand		Pakistan		South Africa	
	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	-	-	0.648	0.101	-	-	0.672	0.023	0.596	0.319
Petroleum/Basic Materials	-	-	0.352	0.179	-	-	0.328	0.052	0.404	0.415
Consumer Cyclicals/Petroleum	0.684	0.103	0.694	0.072	0.768	0.130	0.695	0.039	0.676	0.204
Petroleum/Consumer Cyclicals	0.316	0.215	0.306	0.158	0.232	0.352	0.305	0.098	0.324	0.363
Consumer Non-Cyclicals/Petroleum	0.706	0.119	0.746	0.035	-	-	-	-	0.696	0.198
Petroleum/Consumer Non-Cyclicals	0.294	0.272	0.254	0.103	-	-	-	-	0.304	0.374
Energy/Petroleum	0.630	0.120	-	-	-	-	0.658	0.054	-	-
Petroleum/Energy	0.370	0.199	-	-	-	-	0.342	0.113	-	-
Financials/Petroleum	0.690	0.133	0.603	0.089	0.824	0.124	0.686	0.024	0.691	0.196
Petroleum/Financials	0.310	0.286	0.397	0.132	0.176	0.434	0.314	0.061	0.309	0.366
Healthcare/Petroleum	-	-	0.713	0.038	-	-	-	-	-	-
Petroleum/Healthcare	-	-	0.287	0.095	-	-	-	-	-	-
Industrials/Petroleum	0.680	0.107	0.683	0.098	0.770	0.121	-	-	0.669	0.214
Petroleum/Industrials	0.320	0.222	0.317	0.202	0.230	0.336	-	-	0.331	0.365
Technology/Petroleum	0.687	0.123	0.663	0.087	-	-	-	-	0.631	0.210
Petroleum/Technology	0.313	0.258	0.337	0.167	-	-	-	-	0.369	0.322
Telecommunications Services/Petroleum	-	-	-	-	-	-	-	-	0.585	0.215
Petroleum/Telecommunications Services	-	-	-	-	-	-	-	-	0.415	0.282
Utilities/Petroleum	-	-	0.636	0.013	-	-	0.677	0.028	-	-
Petroleum/Utilities	-	-	0.364	0.024	-	-	0.323	0.063	-	-

Panel D	South Korea		Sweden		Taiwan		Thailand		Turkey	
	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t	w_t	β_t
Basic Materials/Petroleum	0.624	0.143	-	-	0.715	0.110	-	-	0.457	0.225
Petroleum/Basic Materials	0.376	0.225	-	-	0.285	0.252	-	-	0.543	0.187
Consumer Cyclicals/Petroleum	0.665	0.117	0.617	0.245	-	-	0.656	0.107	0.495	0.205
Petroleum/Consumer Cyclicals	0.335	0.221	0.383	0.364	-	-	0.344	0.203	0.505	0.196
Consumer Non-Cyclicals/Petroleum	0.678	0.092	-	-	-	-	-	-	0.509	0.198
Petroleum/Consumer Non-Cyclicals	0.322	0.183	-	-	-	-	-	-	0.491	0.200
Energy/Petroleum	0.552	0.178	-	-	-	-	0.588	0.211	-	-
Petroleum/Energy	0.448	0.214	-	-	-	-	0.412	0.283	-	-
Financials/Petroleum	0.541	0.145	0.569	0.266	0.683	0.103	0.640	0.118	0.431	0.233
Petroleum/Financials	0.459	0.170	0.431	0.342	0.317	0.218	0.360	0.208	0.569	0.178
Healthcare/Petroleum	0.540	0.086	-	-	-	-	-	-	-	-
Petroleum/Healthcare	0.460	0.101	-	-	-	-	-	-	-	-
Industrials/Petroleum	0.541	0.163	0.565	0.290	-	-	0.648	0.106	0.483	0.205
Petroleum/Industrials	0.459	0.189	0.435	0.360	-	-	0.352	0.190	0.517	0.189
Technology/Petroleum	0.603	0.119	-	-	0.659	0.108	-	-	-	-
Petroleum/Technology	0.397	0.176	-	-	0.341	0.202	-	-	-	-
Telecommunications Services/Petroleum	-	-	-	-	-	-	-	-	-	-
Petroleum/Telecommunications Services	-	-	-	-	-	-	-	-	-	-
Utilities/Petroleum	-	-	-	-	-	-	-	-	-	-
Petroleum/Utilities	-	-	-	-	-	-	-	-	-	-

Notes: Petroleum is represented by the Brent grade. w and β denote average weights and hedge ratios (long/short), respectively, of assets in the portfolio comprising a stock sector index and petroleum.

6. Conclusion

In general, the effects of the petroleum price volatility on sectors of net petroleum exporting and importing economies are not expected to be symmetric. From the standpoint of portfolio management, it is essential to be enlightened about the heterogeneity of stock sectors' sensitivities. Therefore, to conduct an examination at the sector level focusing on the extensive range of markets with different levels of development, a unique approach to manually built sector indices utilising the firm-level data is introduced. This study scrutinises the volatility transmissions between spot prices of the Brent crude petroleum and self-constructed stock sector indices of seven petroleum exporting and nineteen petroleum importing nations using the sample 5,768 unique equities listed in *Basic Materials, Consumer Cyclicals, Consumer Non-Cyclicals, Energy, Financials, Healthcare, Industrials, Technology, Telecommunications Services* and *Utilities* sectors from January 03, 2005 to September 28, 2018. The VAR-GARCH process that follows the specification of Ling and McAleer (2003) is employed. The work is further extended by analysing optimal portfolio weights and hedge ratios computed based on the estimates of models for each petroleum and stock sector index pairs.

The empirical results provide evidence of the significant presence of shock and volatility interactions between petroleum and stock sector indices of petroleum exporters and importers. However, it should be emphasised that the direction and magnitude of transmissions vary across the studied markets and sectors, thereby indicating the importance of the sector level analysis. Interestingly, spillovers mostly occur from stock sector indices of petroleum exporting countries, including importers with large petroleum production levels, to petroleum, pointing to advantages from monitoring performance of these countries' stock markets for potential transformations in the petroleum market. On the other hand, transmissions usually take place from petroleum to stock sector indices in the case of petroleum importing countries. The volatility cross effects are more evident for sector indices of Canada and Mexico (petroleum exporters), and Brazil, the United States, Australia, Israel, Japan, Pakistan and South Korea (petroleum importers). The greater number of detected shocks or innovations indicate that past short-term shocks originating from stock sector indices (or petroleum) generally induce more prominent effects on conditional volatility of petroleum (or stock sector indices) than past volatilities, and therefore, should considered by investors and policy makers. For stock sector indices of countries, which are predominantly developing, where some or no interactions were observed, it appears that past own shocks or innovations and volatilities are more important in forecasting the future levels of volatility. Hence, one can conclude that sectors of emerging markets are less sensitive to petroleum price shocks and volatility.

The optimal portfolio weights and hedge ratios vary substantially from one sector to another of petroleum exporting and importing countries. The results suggest that formed portfolios should comprise more sector indices, except some that should have greater holdings of petroleum assets. The analysis of hedge ratios indicates that stock sector indices of Saudi Arabia (net exporter) and China (net importer), where no or little evidence of volatility spillovers were documented, provide better opportunities for hedging exposure to petroleum risks. In sum, adding a petroleum asset to a diversified portfolio of stock sector indices enhances its risk-adjusted performance, which is line with Arouri et al., (2011b, 2012).

Overall, the findings have important implications for international investors and policymakers. Petroleum is among the factors that influence the volatility of stock sector indices in the studied net petroleum exporting and importing countries. Therefore, detecting and understanding the vulnerability of sector indices to fluctuations in petroleum prices are vital for the efficient diversification of investment portfolio holdings and management of risks, and thus, can be utilised to establish investment strategies. Furthermore, policy makers in countries, where significant volatility transmission from petroleum to stock sector indices are reported, should account for these effects when implementing appropriate practices.

References

Arouri, M. E. H., Lahiani, A., & Nguyen, D. K. (2011a). Return and volatility transmission between world oil prices and stock markets of the GCC countries. *Economic Modelling*, 28(4), 1815-1825.

Arouri, M. E. H., Jouini, J., & Nguyen, D. K. (2011b). Volatility spillovers between oil prices and stock sector returns: Implications for portfolio management. *Journal of International Money and Finance*, 30(7), 1387-1405.

Arouri, M. E. H., Jouini, J., & Nguyen, D. K. (2012). On the impacts of oil price fluctuations on European equity markets: Volatility spillover and hedging effectiveness. *Energy Economics*, 34(2), 611-617.

Arouri, M. E. H., Lahiani, A., & Nguyen, D. K. (2015). World gold prices and stock returns in China: Insights for hedging and diversification strategies. *Economic Modelling*, 44, 273-282.

Ashfaq, S., Tang, Y., & Maqbool, R. (2019). Volatility spillover impact of world oil prices on leading Asian energy exporting and importing economies' stock returns. *Energy*, 188, 116002.

Batten, J.A., Kinateder, H., Szilagyi, P.G., & Wagner, N.F. (2021). Hedging stocks with oil. *Energy Economics*, 93, 104422.

Belhassine, O. (2020). Volatility spillovers and hedging effectiveness between the oil market and Eurozone sectors: A tale of two crises. *Research in International Business and Finance*, 53, 101195.

Belhassine, O., & Karamti, C. (2021). Volatility spillovers and hedging effectiveness between oil and stock markets: Evidence from a wavelet-based and structural breaks analysis. Energy Economics, 102, 105513.

Bouri, E., Awartani, B., & Maghyereh, A. (2016). Crude oil prices and sectoral stock returns in Jordan around the Arab uprisings of 2010. *Energy Economics*, 56, 205-214.

British Petroleum, 2018. BP Statistical Review of World Energy 2018. BP, London.

British Petroleum, 2021. BP Statistical Review of World Energy 2021. BP, London.

Chang, C. L., McAleer, M., & Tansuchat, R. (2010). Analyzing and forecasting volatility spillovers, asymmetries and hedging in major oil markets. *Energy Economics*, 32(6), 1445-1455.

Chang, C. L., McAleer, M., & Tansuchat, R. (2011). Crude oil hedging strategies using dynamic multivariate GARCH. Energy Economics, 33(5), 912-923.

Chang, C. L., McAleer, M., & Tansuchat, R. (2013). Conditional correlations and volatility spillovers between crude oil and stock index returns. *North American Journal of Economics and Finance*, 25, 116-138.

Ewing, B. T., & Malik, F. (2016). Volatility spillovers between oil prices and the stock market under structural breaks. *Global Finance Journal*, 29, 12-23.

Hammoudeh, S. M., Yuan, Y., & McAleer, M. (2009). Shock and volatility spillovers among equity sectors of the Gulf Arab stock markets. *The Quarterly Review of Economics and Finance*, 49(3), 829-842.

Hammoudeh, S. M., Yuan, Y., McAleer, M., & Thompson, M. A. (2010). Precious metals–exchange rate volatility transmissions and hedging strategies. *International Review of Economics and Finance*, 19(4), 633-647.

Kroner, K. F., & Sultan, J. (1993). Time-varying distributions and dynamic hedging with foreign currency futures. *The Journal of Financial and Quantitative Analysis*, 28(4), 535-551.

Kroner, K.F., & Ng, V.K. (1998). Modelling asymmetric comovements of asset returns. *The Review of Financial Studies*, 11(4), 817–844.

Lin, B., Wesseh, P. K., & Appiah, M. O. (2014). Oil price fluctuation, volatility spillover and the Ghanaian equity market: Implication for portfolio management and hedging effectiveness. *Energy Economics*, 42, 172-182.

Ling, S., & McAleer, M. (2003). Asymptotic theory for a vector ARMA-GARCH model. *Econometric Theory*, 19(2), 280-310.

Malik, F., & Ewing, B. T. (2009). Volatility transmission between oil prices and equity sector returns. *International Review of Financial Analysis*, 18(3), 95-100.

Malik, F., & Hammoudeh, S. (2007). Shock and volatility transmission in the oil, US and Gulf equity markets. *International Review of Economics and Finance*, 16(3), 357-368.

Mateus, C., Chinthalapati, R., & Mateus, B. I. (2017). Intraday industry-specific spillover effect in European equity markets. *The Quarterly Review of Economics and Finance*, 63, 278-298.

Mensi, W., Beljid, M., Boubaker, A., & Managi, S. (2013). Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Economic Modelling*, 32, 15-22.

Ramos, S. B., & Veiga, H. (2013). Oil price asymmetric effects: Answering the puzzle in international stock markets. *Energy Economics*, 38, 136-145.

Sadorsky, P. (2012). Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics*, 34(1), 248-255.

Salisu, A. A., & Mobolaji, H. (2013). Modeling returns and volatility transmission between oil price and US-Nigeria exchange rate. *Energy Economics*, 39, 169-176.

Salisu, A. A., & Oloko, T. F. (2015). Modeling oil price–US stock nexus: A VARMA–BEKK–AGARCH approach. *Energy Economics*, 50, 1-12.

Sarwar, S., Khalfaoui, R., Waheed, R, & Dastgerdi, H. G. (2019). Volatility spillovers and hedging: Evidence from Asian oil-importing countries. *Resources Policy*, 61, 479-488.

Sarwar, S., Tiwari, A. K., & Tingqiu, C. (2020). Analyzing volatility spillovers between oil market and Asian stock markets. *Resources Policy*, 66, 101608.

Smyth, R., & Narayan, P. K. (2018). What do we know about oil prices and stock returns? *International Review of Financial Analysis*, 57, 148-156.

Vardar, G., Coskun, Y., & Yelkenci, T. (2018). Shock transmission and volatility spillover in stock and commodity markets: evidence from advanced and emerging markets. *Eurasian Economic Review*, 8, 231–288.

Wang, Y., & Liu, L. (2016). Crude oil and world stock markets: volatility spillovers, dynamic correlations, and hedging. *Empirical Economics*, 50, 1481-1509.

Yousaf, I., & Hassan, A. (2019). Linkages between crude oil and emerging Asian stock markets: New evidence from the Chinese stock market crash. *Finance Research Letters*, 31, 207-217.

Appendix

Table A1: Automatic selection of lag length for the mean equation based on the Schwarz Bayesian Criterion (SBC).

Panel A	Argentina	Australia	Brazil	Canada	Chile	China	Denmark	Eurozone	India
	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag
Basic Materials	1	1	1	1	-	1	-	0	1
Consumer Cyclicals	-	0	1	1	-	0	0	0	1
Consumer Non-Cyclicals	1	0	0	0	0	0	-	0	1
Energy	1	1	1	1	-	1	-	0	1
Financials	1	0	1	1	1	0	1	1	1
Healthcare	-	0	-	0	-	0	0	0	0
Industrials	-	1	1	1	1	0	0	0	1
Technology	-	-	-	0	-	0	-	0	1
Telecommunications Services	-	0	-	0	-	-	-	0	-
Utilities	1	0	0	1	1	-	-	0	1

Panel B	Indonesia	Israel	Japan	Mexico	New Zealand	Norway	Pakistan	Russia	Saudi Arabia
	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag
Basic Materials	1	-	1	1	-	-	1	1	1
Consumer Cyclicals	-	1	1	1	1	0	1	-	1
Consumer Non-Cyclicals	1	1	1	1	-	0	-	-	1
Energy	1	0	-	-	-	0	1	0	1
Financials	1	0	1	1	0	0	1	-	1
Healthcare	-	-	1	-	-	-	-	-	-
Industrials	-	0	1	1	1	0	-	-	1
Technology	-	0	1	-	-	-	-	-	-
Telecommunications Services	-	-	-	-	-	-	-	-	-
Utilities	-	-	0	-	-	-	0	1	-

Panel C	South Africa	South Korea	Sweden	Taiwan	Thailand	Turkey	United Kingdom	United States
	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag	SBC Lag
Basic Materials	0	1	-	1	-	0	0	1
Consumer Cyclicals	1	1	0	-	0	1	0	1
Consumer Non-Cyclicals	0	1	-	-	-	0	0	1
Energy	-	1	-	-	1	-	0	1
Financials	0	1	0	1	0	0	0	1
Healthcare	-	1	-	-	-	-	0	1
Industrials	1	1	0	-	0	0	0	1
Technology	0	1	-	1	-	-	-	1
Telecommunications Services	0	-	-	-	-	-	-	1
Utilities	-	-	-	-	-	-	0	1

Table A2: The Schwarz Bayesian Criterion (SBC) figures of different GARCH (*p*,*q*) processes.

Panel A	Argentina		Australia		Brazil		Canada		Chile		China	
	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)
Basic Materials	7.787*	7.798	8.031*	8.041	8.443*	8.456	8.201*	8.215	-	-	8.311*	8.325
Consumer Cyclicals	-	-	7.385*	7.399	8.378*	8.390	6.935*	6.945	-	-	8.121*	8.135
Consumer Non-Cyclicals	7.579*	7.589	7.384*	7.397	8.116*	8.131	6.773*	6.789	7.307*	7.318	8.041*	8.051
Energy	7.969*	7.985^{+}	8.112*	8.126	8.507*	8.515	7.697*	7.710	-	-	8.403*	8.413
Financials	8.164*	8.176^{+}	7.382*	7.402^{+}	8.428*	8.437	6.742*	6.758	7.079*	7.094^{+}	8.206*	8.222
Healthcare	-	-	7.417*	7.429	-	-	7.669*	7.681	-	-	8.035*	8.049
Industrials	-	-	7.573*	7.583	8.176*	8.191	6.987*	7.003	7.554*	7.564	8.107*	8.189^{+}
Technology	-	-	-	-	-	-	7.309*	7.321	-	-	8.314*	8.328^{+}
Telecommunications Services	-	-	7.503*	7.516	-	-	6.924*	6.934	-	-	-	-
Utilities	8.232*	8.243^{+}	7.463*	7.479	8.195*	8.203	6.919*	6.923	7.103*	7.113	-	-

Panel B	Denmark		Eurozone		India		Indonesia		Israel	
	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)
Basic Materials	-	-	7.354*	7.369	7.994*	8.005	8.299*	8.308	-	-
Consumer Cyclicals	7.309*	7.317	7.256*	7.270	7.755*	7.763	-	-	7.570*	7.575
Consumer Non-Cyclicals	-	-	6.896*	6.913	7.553*	7.561	8.005*	8.089^{+}	7.471*	7.480
Energy	-	-	7.291*	7.306	8.004*	8.120^{+}	8.426*	8.437	7.799*	7.808
Financials	7.182*	7.197	7.653*	7.669	8.297*	8.312	8.098*	8.112	7.529*	7.535
Healthcare	7.474*	7.486	7.183*	7.199	7.595*	7.607^{+}	-	-	-	-
Industrials	7.562*	7.578	7.325*	7.340	8.187*	8.197	-	-	7.571*	7.582
Technology	-	-	7.457*	7.472	7.802*	7.819	-	-	7.563*	7.571
Telecommunications Services	-	-	7.199*	7.211	-	-	-	-	-	-
Utilities	-	-	7.233*	7.246	8.082*	8.090	-	-	-	-

Panel C	Japan		Mexico		New Zealand		Norway		Pakistan	
	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)
Basic Materials	7.752*	7.852^{+}	7.899*	7.914	-	-	-	-	7.446*	7.533^{+}
Consumer Cyclicals	7.535*	7.564^{+}	7.642*	7.649	7.214*	7.225	7.698*	7.706	7.345*	7.360
Consumer Non-Cyclicals	7.270*	7.341^{+}	7.441*	7.453	-	-	7.974*	8.048^{+}	-	-
Energy	-	-	-	-	-	-	8.244*	8.257	7.53*	7.547^{+}
Financials	7.925*	7.948^{+}	7.797*	7.806	6.954*	6.968	7.726*	7.728^{+}	7.344*	7.366^{+}
Healthcare	7.420*	7.497^{+}	-	-	-	-	-	-	-	-
Industrials	7.597*	7.674^{+}	7.777*	7.790	7.188*	7.201	7.634*	7.646	-	-
Technology	7.677*	7.745^{+}	-	-	-	-	-	-	-	-
Telecommunications Services	-	-	-	-	-	-	-	-	-	-
Utilities	7.733*	7.735	-	-	-	-	-	-	7.444*	7.449^{+}

Panel D	Russia		Saudi Arabia		South Africa		South Korea		Sweden	
	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)
Basic Materials	8.124*	8.125⁺	7.583*	7.587	7.833*	7.850	7.764*	7.772	-	-
Consumer Cyclicals	-	-	7.724*	7.726	7.589*	7.603	7.590*	7.602	7.762*	7.775
Consumer Non-Cyclicals	-	-	8.017*	8.022	7.525*	7.543	7.545*	7.557	-	-
Energy	8.024*	8.041	7.970*	7.971⁺	-	-	8.025*	8.036	-	-
Financials	-	-	7.803*	7.810⁺	7.541*	7.552	8.065*	8.076	7.910*	7.925
Healthcare	-	-	-	-	-	-	8.084*	8.097	-	-
Industrials	-	-	7.954	7.952*	7.620*	7.630	8.066*	8.082	7.928*	7.944
Technology	-	-	-	-	7.739*	7.748	7.833*	7.844	-	-
Telecommunications Services	-	-	-	-	7.904*	7.921	-	-	-	-
Utilities	8.503*	8.513	-	-	-	-	-	-	-	-

Panel E	Taiwan		Thailand		Turkey		United Kingdom		United States	
	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)	(*p=1,q=1*)	(*p=2,q=2*)
Basic Materials	7.389*	7.397	-	-	8.373*	8.400⁺	8.040*	8.051	7.344*	7.358
Consumer Cyclicals	-	-	7.622*	7.632	8.233*	8.238	7.395*	7.407	7.143*	7.154
Consumer Non-Cyclicals	-	-	-	-	8.181*	8.189	6.972*	6.988	6.395*	6.406
Energy	-	-	7.934	7.932*	-	-	7.484*	7.494	7.735*	7.744
Financials	7.474*	7.485	7.695*	7.696	8.464*	8.471	7.576*	7.593	7.236*	7.250
Healthcare	-	-	-	-	-	-	7.155*	7.166	6.765*	6.779
Industrials	-	-	7.671	7.667*	8.277*	8.379⁺	7.298*	7.311	7.039*	7.052
Technology	7.600*	7.610	-	-	-	-	-	-	7.245*	7.256
Telecommunications Services	-	-	-	-	-	-	-	-	7.387*	7.401
Utilities	-	-	-	-	-	-	7.216*	7.225	6.825*	6.829

Notes: *p* and *q* are the number of GARCH and ARCH terms, respectively. * indicates the lowest value of the Schwarz Bayesian Criterion and ⁺ denotes no convergence.

Table A3: ARCH and unit root tests.

Panel A	Argentina		Australia		Brazil		Canada		Chile	
	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF
Brent	215.69***	-57.29***	207.79***	-57.70***	215.95***	-57.81***	214.82***	-57.92***	172.42***	-57.77***
Basic Materials	266.65***	-35.36***	1038.29***	-37.25***	897.55***	-53.13***	730.32***	-55.65***	-	-
Consumer Cyclicals	-	-	1100.05***	-38.59***	690.07***	-54.18***	534.13***	-53.46***	-	-
Consumer Non-Cyclicals	255.10***	-35.48***	825.24***	-60.98***	694.94***	-54.45***	436.98***	-56.67***	635.56***	-37.58***
Energy	249.00***	-37.12***	1153.13***	-53.06***	692.40***	-55.70***	775.20***	-53.80***	-	-
Financials	366.69***	-52.15***	877.06***	-27.58***	771.89***	-52.53***	622.40***	-27.83***	726.93***	-52.22***
Healthcare	-	-	836.76***	-62.43***	-	-	387.70***	-54.64***	-	-
Industrials	-	-	1113.7***	-54.98***	788.00***	-52.71***	744.00***	-53.39***	373.21***	-51.74***
Technology	-	-	-	-	-	-	875.95***	-56.04***	-	-
Telecommunications Services	-	-	719.68***	-34.16***	-	-	487.92***	-57.12***	-	-
Utilities	371.51***	-47.73***	880.81***	-59.14***	424.90***	-55.46***	444.16***	-52.60***	878.59***	-52.87***

Panel B	China		Denmark		Eurozone		India		Indonesia	
	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF
Brent	77.52***	-56.45***	216.03***	-57.70***	214.70***	-58.6***	231.76***	-57.24***	113.74***	-55.91***
Basic Materials	412.23***	-54.15***	-	-	638.52***	-54.36***	363.36***	-51.73***	385.17***	-53.20***
Consumer Cyclicals	350.56***	-53.95***	519.06***	-54.80***	422.50***	-54.38***	303.37***	-49.66***	-	-
Consumer Non-Cyclicals	405.2***	-53.95***	-	-	552.78***	-57.31***	530.59***	-52.59***	402.23***	-35.85***
Energy	313.42***	-54.68***	-	-	725.23***	-56.01***	317.00***	-51.98***	481.64***	-51.09***
Financials	235.14***	-55.87***	648.81***	-53.72***	352.87***	-53.83***	261.12***	-50.92***	396.56***	-51.35***
Healthcare	352.13***	-42.24***	339.51***	-58.89***	547.69***	-58.46***	407.64***	-53.26***	-	-
Industrials	458.43***	-53.85***	694.21***	-55.93***	531.10***	-54.80***	367.43***	-50.31***	-	-
Technology	336.03***	-55.20***	-	-	552.46***	-56.97***	672.85***	-55.12***	-	-
Telecommunications Services	-	-	-	-	482.91***	-56.60***	-	-	-	-
Utilities	-	-	-	-	593.15***	-55.30***	308.91***	-52.88***	-	-

Panel C	Israel		Japan		Mexico		New Zealand		Norway	
	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF
Brent	219.48***	-57.44***	101.61***	-56.18***	178.21***	-57.93***	119.28***	-57.98***	218.36***	-57.89***
Basic Materials	-	-	569.56***	-61.80***	1015.23***	-51.07***	-	-	-	-
Consumer Cyclicals	305.37***	-51.86***	667.55***	-64.86***	770.79***	-51.40***	896.68***	-54.13***	606.47***	-54.48***
Consumer Non-Cyclicals	325.74***	-52.26***	383.04***	-67.23***	801.27***	-52.56***	-	-	366.91***	-57.29***
Energy	210.29***	-54.50***	-	-	-	-	-	-	596.67***	-56.11***
Financials	546.03***	-55.41***	507.18***	-60.38***	730.45***	-50.08***	976.58***	-57.05***	301.35***	-55.68***
Healthcare	-	-	569.49***	-46.48***	-	-	-	-	-	-
Industrials	466.29***	-53.73***	607.01***	-63.58***	692.88***	-51.76***	888.36***	-53.79***	389.57***	-54.67***
Technology	496.63***	-55.77***	735.63***	-63.97***	-	-	-	-	-	-
Telecommunications Services	-	-	-	-	-	-	-	-	-	-
Utilities	-	-	251.48***	-59.56***	-	-	-	-	-	-

Panel D	Pakistan		Russia		Saudi Arabia		South Africa		South Korea	
	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF
Brent	277.94***	-57.42***	179.59***	-58.33***	169.02***	-57.08***	213.37***	-57.81***	195.51***	-57.08***
Basic Materials	725.04***	-48.09***	490.68***	-53.30***	822.32***	-25.5***	459.90***	-54.12***	764.84***	-36.84***
Consumer Cyclicals	425.39***	-44.95***	-	-	911.00***	-24.86***	277.02***	-52.88***	567.73***	-37.64***
Consumer Non-Cyclicals	-	-	-	-	969.88***	-23.56***	313.44***	-54.05***	601.21***	-36.78***
Energy	624.95***	-48.17***	603.12***	-55.83***	909.77***	-24.92***	-	-	689.28***	-34.58***
Financials	567.90***	-46.75***	-	-	572.10***	-30.66***	394.30***	-53.39***	589.98***	-56.55***
Healthcare	-	-	-	-	-	-	-	-	546.83***	-37.56***
Industrials	-	-	-	-	950.40***	-24.45***	289.00***	-52.62***	668.85***	-53.26***
Technology	-	-	-	-	-	-	582.30***	-55.34***	604.11***	-56.05***
Telecommunications Services	-	-	-	-	-	-	368.25***	-56.06***	-	-
Utilities	585.77***	-54.36***	475.79***	-52.47***	-	-	-	-	-	-

Panel E	Sweden		Taiwan		Thailand		Turkey		United Kingdom		United States	
	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF	ARCH	ADF
Brent	187.30***	-58.24***	89.27***	-57.03***	70.76***	-55.34***	223.85***	-57.35***	209.50***	-57.89***	203.41***	-57.81***
Basic Materials	-	-	378.79***	-52.18***	-	-	258.65***	-54.63***	895.48***	-58.21***	886.10***	-60.65***
Consumer Cyclicals	365.11***	-57.67***	-	-	285.83***	-55.15***	348.53***	-53.25***	439.41***	-30.10***	1013.38***	-57.80***
Consumer Non-Cyclicals	-	-	-	-	-	-	332.66***	-54.40***	754.17***	-37.93***	956.77***	-46.86***
Energy	-	-	-	-	371.57***	-37.45***	-	-	905.26***	-57.99***	849.97***	-45.29***
Financials	547.83***	-59.01***	533.22***	-55.38***	306.72***	-53.80***	348.88***	-54.19***	388.72***	-29.18***	677.99***	-66.58***
Healthcare	-	-	-	-	-	-	-	-	833.58***	-60.27***	917.78***	-34.23***
Industrials	457.46***	-59.60***	-	-	300.92***	-54.75***	453.89***	-53.54***	562.01***	-30.38***	857.96***	-60.98***
Technology	-	-	409.05***	-53.32***	-	-	-	-	-	-	756.57***	-61.42***
Telecommunications Services	-	-	-	-	-	-	-	-	-	-	857.78***	-44.69***
Utilities	-	-	-	-	-	-	-	-	599.69***	-43.85***	1049.17***	-45.67***

Notes: *** indicates the significance level at 1%. ADF is the Augmented Dickey-Fuller unit root test and ARCH is the Engle's test for autoregressive conditional heteroscedasticity of order five. The test statistics at orders from one to four are also significant at 1% level.

Table A4: The VAR-GARCH model estimates for stock sector indices of petroleum exporting countries.

Panel A: Argentina	Basic Materials & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Utilities & Brent
Mean Equation					
$\mu_{1,0}$	0.0130	0.0554**	0.0582**	0.0770***	0.0573*
$\phi_{1,1}$	0.1634***	0.1830***	0.0932***	0.1262***	0.2232***
$\phi_{1,2}$	0.0070	-0.0014	0.0223*	-0.0014	0.0114
$\mu_{2,0}$	0.0353	0.0391	0.0359	0.0337	0.0310
$\phi_{2,1}$	0.0193	0.0322	0.0539***	0.0234**	0.0089
$\phi_{2,2}$	0.0093	0.0077	0.0002	0.0087	0.0124
Variance Equation					
$c_{1,1}$	0.2331***	0.2189**	0.1501***	0.2287***	0.3101***
$c_{2,2}$	0.0058	0.0071	0.0200**	0.0179**	0.0177*
$\alpha_{1,1}$	0.2493***	0.1977***	0.1515***	0.2023***	0.2285***
$\alpha_{1,2}$	-0.0041	0.0014	-0.0041	-0.0055	-0.0101***
$\alpha_{2,1}$	0.0048	0.0036	0.0030	0.0060	-0.0010
$\alpha_{2,2}$	0.0373***	0.0382***	0.0400***	0.0398***	0.0405***
$\beta_{1,1}$	0.6792***	0.7110***	0.8166***	0.7523***	0.7198***
$\beta_{1,2}$	0.0122	-0.0001	0.0030	0.0087	0.0098**
$\beta_{2,1}$	-0.0028	-0.0018	-0.0042	-0.0074	0.0005
$\beta_{2,2}$	0.9609***	0.9599***	0.9568***	0.9585***	0.9565***
$\rho_{2,1}$	0.1517***	0.1691***	0.2726***	0.1362***	0.1161***
$\alpha_{1,1} + \beta_{1,1}$	0.9285	0.9087	0.9681	0.9546	0.9483
$\alpha_{2,2} + \beta_{2,2}$	0.9983	0.9981	0.9968	0.9982	0.9970
Log L	-13039.739	-12689.705	-13347.031	-13675.663	-13789.839
AIC	7.756	7.548	7.938	8.133	8.201
SBC	7.787	7.579	7.969	8.164	8.232
Diagnostics of Standardised Residuals					
	Basic Materials	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Utilities**
Q(20)	59.068***	43.359***	35.036**	35.097**	39.538***
$Q^2(20)$	20.337	4.394	7.298	17.341	15.919
Q(10)	36.55***	26.35***	21.031**	16.596*	23.133**
$Q^2(10)$	7.817	2.049	3.913	9.831	13.492
	Brent	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	21.345	21.478	21.548	22.164	23.412
$Q^2(20)$	33.071**	33.803**	37.703**	36.466**	35.182**
Q(10)	10.394	10.307	9.831	10.424	10.877
$Q^2(10)$	12.406	12.461	12.556	12.444	12.552

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3369.

Panel B: Canada	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent	Telecommunications Services & Brent	Utilities & Brent
Mean Equation										
$\mu_{1,0}$	0.0036	0.0287*	0.0375**	0.0236	0.0296**	0.0341	0.0387**	0.0484**	0.0273	0.0151
$\phi_{1,1}$	0.0748***	0.0664***	0.0233	0.1331***	0.1001***	0.0446***	0.0760***	0.0410**	0.0287	0.1082***
$\phi_{1,2}$	-0.0089	-0.0101	-0.0044	-0.0373**	-0.0098	0.0017	-0.0084	-0.0010	0.0003	-0.0035
$\mu_{2,0}$	0.0467	0.0368	0.0280	0.0520**	0.0341	0.0320	0.0338	0.0273	0.0331	0.0397
$\phi_{2,1}$	0.1032***	0.0979***	0.0428	0.2263***	0.1144***	0.0398**	0.1063***	0.0641**	0.0496	0.1333***
$\phi_{2,2}$	-0.0173	0.00003	0.0147	-0.0923***	-0.0050	0.0114	-0.0045	0.0066	0.0115	-0.0026
Variance Equation										
$c_{1,1}$	0.0484***	0.0217***	0.0175***	0.0291**	0.0075***	0.0777**	0.0247***	0.0315**	0.0277**	0.0416**
$c_{2,2}$	0.0140*	0.0214*	0.0204**	0.0189***	0.0190***	0.0205**	0.0269***	0.0257**	0.0289**	0.0297**
$\alpha_{1,1}$	0.0610***	0.0654***	0.0536***	0.0804***	0.0894***	0.1111***	0.0894***	0.0723***	0.0663***	0.0986***
$\alpha_{1,2}$	0.0024	0.0021	-0.00002	0.0022	-0.0007	-0.0042	-0.0026	-0.0017	-0.0012	-0.0047*
$\alpha_{2,1}$	0.0083*	0.0291	0.0407*	0.0169**	0.0447***	0.0164*	0.0516**	0.0477***	0.0532**	0.0459*
$\alpha_{2,2}$	0.0359***	0.0381***	0.0363***	0.0304***	0.0349***	0.0384***	0.0338***	0.0325***	0.0370***	0.0349***
$\beta_{1,1}$	0.9276***	0.9084***	0.9141***	0.8835***	0.8894***	0.8418***	0.8625***	0.9028***	0.8891***	0.8254***
$\beta_{1,2}$	-0.0014	-0.0001	0.0031	0.0219	0.0047*	0.0147*	0.0118*	0.0039	0.0064	0.0172
$\beta_{2,1}$	-0.0072	-0.0324	-0.0448	-0.0129	-0.0492***	-0.0196	-0.0723**	-0.0530**	-0.0695	-0.0665
$\beta_{2,2}$	0.9596***	0.9576***	0.9597***	0.9605***	0.9616***	0.9592***	0.9661***	0.9632***	0.9604***	0.9640***
$\rho_{2,1}$	0.3278***	0.3147***	0.2785***	0.4972***	0.3459***	0.2181***	0.3399***	0.2477***	0.2699***	0.3465***
$\alpha_{1,1}+\beta_{1,1}$	0.9886	0.9738	0.9677	0.9639	0.9788	0.9529	0.9519	0.9751	0.9554	0.9240
$\alpha_{2,2}+\beta_{2,2}$	0.9955	0.9957	0.9960	0.9909	0.9964	0.9975	0.9999	0.9957	0.9975	0.9989
Log L	-14078.053	-11893.806	-11614.220	-13208.297	-11560.269	-13159.398	-11982.813	-12539.178	-11873.936	-11865.405
AIC	8.171	6.905	6.743	7.667	6.711	7.638	6.956	7.279	6.893	6.888
SBC	8.201	6.935	6.773	7.697	6.742	7.669	6.987	7.309	6.924	6.919
Diagnostics of Standardised Residuals										
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**	**Telecommunications Services**	**Utilities**
Q(20)	13.560	21.099	30.095*	12.424	23.093	16.365	19.116	17.705	24.265	21.416
Q²(20)	13.104	20.746	25.814	13.187	14.406	14.568	8.023	12.457	8.410	5.459
Q(10)	5.303	14.482	16.702*	5.788	11.468	6.901	7.467	8.657	15.342	12.964
Q²(10)	9.107	6.017	9.260	3.283	9.729	10.232	4.545	6.099	3.886	2.163
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	15.654	15.635	15.238	15.167	15.423	15.693	15.521	15.521	15.750	16.175
Q²(20)	16.388	17.126	17.240	20.333	17.386	16.656	18.297	15.733	15.306	18.462
Q(10)	6.050	6.854	6.858	5.168	6.667	7.244	6.330	6.580	6.916	6.553
Q²(10)	8.067	8.434	8.090	10.789	8.398	8.328	8.153	7.186	7.844	9.440

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3452.

Panel C: Denmark	Consumer Cyclicals & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent
Mean Equation				
$\mu_{1,0}$	0.0320**	0.0450**	0.0725***	0.0652***
$\phi_{1,1}$	-0.0018	0.0502***	-0.0112	0.0285*
$\phi_{1,2}$	0.0162*	0.0052	-0.0004	0.0062
$\mu_{2,0}$	0.0391	0.0431	0.0457	0.0460*
$\phi_{2,1}$	0.0001	-0.0452*	-0.0467*	-0.0161
$\phi_{2,2}$	0.0209	0.0289	0.0243	0.0224
Variance Equation				
$c_{1,1}$	0.0424*	0.0260***	0.0898***	0.0387***
$c_{2,2}$	0.0256*	0.0183**	0.0278**	0.0193**
$\alpha_{1,1}$	0.0814***	0.0893***	0.0992***	0.0869***
$\alpha_{1,2}$	0.0059	0.0007	0.0064	0.0046
$\alpha_{2,1}$	0.0232	0.0107	0.0118	0.0058
$\alpha_{2,2}$	0.0409***	0.0411***	0.0419***	0.0417***
$\beta_{1,1}$	0.8779***	0.8926***	0.8371***	0.8941***
$\beta_{1,2}$	0.0002	0.00005	0.0022	-0.0032
$\beta_{2,1}$	-0.0355	-0.0149	-0.0237	-0.0093
$\beta_{2,2}$	0.9584***	0.9568***	0.9577***	0.9563***
$\rho_{2,1}$	0.2259***	0.2622***	0.2309***	0.2951***
$\alpha_{1,1} + \beta_{1,1}$	0.9593	0.9819	0.9363	0.9810
$\alpha_{2,2} + \beta_{2,2}$	0.9993	0.9978	0.9996	0.9980
Log L	-12492.030	-12272.405	-12774.310	-12926.577
AIC	7.279	7.151	7.443	7.532
SBC	7.309	7.182	7.474	7.562
Diagnostics of Standardised Residuals				
	Consumer Cyclicals	**Financials**	**Healthcare**	**Industrials**
Q(20)	26.263	27.536	16.712	14.031
$Q^2(20)$	20.858	16.179	21.625	23.240
Q(10)	8.109	11.468	11.370	7.897
$Q^2(10)$	9.204	9.132	13.869	14.703
	Brent	**Brent**	**Brent**	**Brent**
Q(20)	16.470	17.380	16.795	16.609
$Q^2(20)$	14.048	13.723	13.255	12.995
Q(10)	9.163	9.436	9.285	9.057
$Q^2(10)$	10.671	10.000	9.841	9.839

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3439.

Panel D: Mexico	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Financials & Brent	Industrials & Brent
Mean Equation					
$\mu_{1,0}$	0.0467*	0.0459**	0.0613***	0.0401	0.0605***
$\phi_{1,1}$	0.1377***	0.0995***	0.1001***	0.1511***	0.1214***
$\phi_{1,2}$	-0.0092	-0.0016	-0.0166	-0.0148	-0.0177
$\mu_{2,0}$	0.0467	0.0395	0.0415	0.0479	0.0427
$\phi_{2,1}$	0.0758***	0.0686***	0.0675***	0.0643***	0.0514***
$\phi_{2,2}$	-0.0080	0.0027	0.0003	-0.0027	0.0019
Variance Equation					
$c_{1,1}$	0.0690***	0.0651***	0.0554***	0.0873***	0.1079***
$c_{2,2}$	0.0245***	0.0218**	0.0308***	0.0273***	0.0264*
$\alpha_{1,1}$	0.1063***	0.1089***	0.1124***	0.1304***	0.1250***
$\alpha_{1,2}$	0.0016	0.0001	-0.0031	0.0025	0.0023
$\alpha_{2,1}$	0.0145**	0.0209*	0.0378***	0.0229***	0.0207*
$\alpha_{2,2}$	0.0380***	0.0366***	0.0353***	0.0370***	0.0375***
$\beta_{1,1}$	0.8647***	0.8456***	0.8433***	0.8288***	0.8028***
$\beta_{1,2}$	0.0061	0.0121*	0.0115**	0.0072	0.0202
$\beta_{2,1}$	-0.018**	-0.0254	-0.0513***	-0.0298***	-0.0279
$\beta_{2,2}$	0.9592***	0.9613***	0.9643***	0.9621***	0.9614***
$\rho_{2,1}$	0.2769***	0.2320***	0.2306***	0.2308***	0.2312***
$\alpha_{1,1} + \beta_{1,1}$	0.9711	0.9546	0.9557	0.9592	0.9278
$\alpha_{2,2} + \beta_{2,2}$	0.9972	0.9979	0.9996	0.9991	0.9988
Log L	-13588.486	-13143.241	-12795.544	-13411.266	-13376.862
AIC	7.869	7.611	7.410	7.766	7.747
SBC	7.899	7.642	7.441	7.797	7.777
Diagnostics of Standardised Residuals					
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Financials**	**Industrials**
Q(20)	27.643	23.671	22.589	16.096	30.434
Q²(20)	15.170	18.520	13.179	16.178	20.862
Q(10)	12.643	9.786	8.362	8.230	9.912
Q²(10)	7.796	12.481	9.146	9.788	13.771
	Brent	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	16.930	17.866	17.679	19.514	18.113
Q²(20)	38.563***	37.883***	40.005***	37.281**	38.888***
Q(10)	7.560	7.988	8.270	8.926	8.264
Q²(10)	7.693	6.980	7.377	7.265	7.325

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3460.

Panel E: Norway	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Industrials & Brent
Mean Equation					
$\mu_{1,0}$	0.0414*	0.0828***	0.0123	0.0280	0.0234
$\phi_{1,1}$	0.0150	0.0159	0.0042	0.0075	0.0245
$\phi_{1,2}$	0.0119	-0.0003	0.0992***	0.0380**	0.0463***
$\mu_{2,0}$	0.0472	0.0410	0.0536	0.0503	0.0451
$\phi_{2,1}$	0.0067	0.0006	0.0236	0.0124	0.0160
$\phi_{2,2}$	0.0154	0.0154	0.0051	0.0179	0.0148
Variance Equation					
$c_{1,1}$	0.0478***	0.1194***	0.1020***	0.0363*	0.0462***
$c_{2,2}$	0.0240***	0.0265**	0.0280***	0.0233***	0.0225***
$\alpha_{1,1}$	0.0748***	0.0765***	0.0662***	0.0672***	0.0753***
$\alpha_{1,2}$	0.0107***	0.0044	0.0102	0.0132*	0.0040
$\alpha_{2,1}$	0.0092	0.0075	0.0069	0.0086	0.0032
$\alpha_{2,2}$	0.0406***	0.0386***	0.0339***	0.0397***	0.0405***
$\beta_{1,1}$	0.9077***	0.8745***	0.9056***	0.9181***	0.9029***
$\beta_{1,2}$	-0.0106***	0.0049	0.0002	-0.0107*	-0.0019
$\beta_{2,1}$	-0.0126*	-0.0126	-0.0078	-0.0127	-0.0072
$\beta_{2,2}$	0.9561***	0.9592***	0.9594***	0.9579***	0.9569***
$\rho_{2,1}$	0.3084***	0.2948***	0.4945***	0.3552***	0.3628***
$\alpha_{1,1} + \beta_{1,1}$	0.9825	0.9509	0.9718	0.9854	0.9781
$\alpha_{2,2} + \beta_{2,2}$	0.9967	0.9977	0.9933	0.9976	0.9974
Log L	-13217.491	-13693.680	-14159.086	-13266.094	-13107.627
AIC	7.668	7.944	8.213	7.696	7.604
SBC	7.698	7.974	8.244	7.726	7.634
Diagnostics of Standardised Residuals					
	Consumer Cyclicals	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Industrials**
Q(20)	18.716	20.724	13.787	24.494	26.299
$Q^2(20)$	15.970	9.034	18.494	15.278	14.510
Q(10)	7.762	3.221	5.639	10.638	15.935
$Q^2(10)$	11.817	5.887	11.951	5.962	8.519
	Brent	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	16.239	16.443	15.140	15.475	15.717
$Q^2(20)$	14.265	13.927	13.561	12.944	13.940
Q(10)	7.946	8.286	7.222	7.350	7.509
$Q^2(10)$	8.915	8.437	7.704	8.061	8.310

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3454.

Panel F: Russia	Basic Materials & Brent	Energy & Brent	Utilities & Brent
Mean Equation			
$\mu_{1,0}$	0.0823**	0.057**	0.0577
$\phi_{1,1}$	0.0516**	0.0095	0.0977***
$\phi_{1,2}$	0.0163	0.0515***	-0.0199
$\mu_{2,0}$	0.0594*	0.0469	0.0659**
$\phi_{2,1}$	-0.0010	-0.0040	0.0144
$\phi_{2,2}$	0.0161	0.0175	0.0091
Variance Equation			
$c_{1,1}$	0.1550**	0.0985***	0.2546**
$c_{2,2}$	0.0317***	0.0214***	0.0173**
$\alpha_{1,1}$	0.1007***	0.0782***	0.1968***
$\alpha_{1,2}$	-0.0040	-0.0012	0.0066
$\alpha_{2,1}$	0.0106**	0.0077**	0.0054
$\alpha_{2,2}$	0.0284***	0.0266***	0.0298***
$\beta_{1,1}$	0.8828***	0.9061***	0.7849***
$\beta_{1,2}$	-0.0108	-0.0067	-0.0042
$\beta_{2,1}$	-0.0114**	-0.0058	-0.0050
$\beta_{2,2}$	0.9647***	0.9655***	0.9660***
$\rho_{2,1}$	0.3655***	0.4360***	0.2990***
$\alpha_{1,1} + \beta_{1,1}$	0.9836	0.9842	0.9817
$\alpha_{2,2} + \beta_{2,2}$	0.9932	0.9920	0.9958
Log L	-13803.312	-13631.739	-14449.252
AIC	8.094	7.993	8.472
SBC	8.124	8.024	8.503
Diagnostics of Standardised Residuals			
	Basic Materials	**Energy**	**Utilities**
Q(20)	14.667	18.325	43.323***
Q²(20)	4.008	6.506	7.321
Q(10)	4.197	6.574	31.195***
Q²(10)	1.868	3.442	4.925
	Brent	**Brent**	**Brent**
Q(20)	15.680	16.086	15.697
Q²(20)	12.916	9.775	11.801
Q(10)	8.272	8.343	8.760
Q²(10)	4.653	4.105	4.769

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3417.

Panel G: Saudi Arabia	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Industrials & Brent
Mean Equation						
$\mu_{1,0}$	0.0553***	0.0433**	0.0527**	0.0465*	0.0197	0.0415*
$\phi_{1,1}$	0.0940***	0.1136***	0.1063***	0.0864***	0.1599***	0.1254***
$\phi_{1,2}$	0.0494***	0.0290***	0.0328**	0.0311**	0.0230**	0.0395***
$\mu_{2,0}$	0.0401	0.0449	0.0475	0.0370	0.0359	0.0439*
$\phi_{2,1}$	0.0104	0.0134	-0.0062	-0.0001	-0.0058	0.0008
$\phi_{2,2}$	0.0227	0.0227	0.0234	0.0226	0.0213	0.0247
Variance Equation						
$c_{1,1}$	0.0408*	0.0406*	0.0777*	0.0651**	0.1093	0.0709
$c_{2,2}$	0.0122**	0.0124**	0.0127**	0.0122*	0.0108	0.0121*
$\alpha_{1,1}$	0.1682***	0.1756***	0.2096***	0.1351***	0.1431***	0.1785***
$\alpha_{1,2}$	0.0057	0.0123	0.0194	0.0074	0.0066	0.0136
$\alpha_{2,1}$	0.0067	0.0078	0.0059	0.0057	0.0122	0.0057
$\alpha_{2,2}$	0.0333***	0.0350***	0.0361***	0.0348***	0.0296***	0.0347***
$\beta_{1,1}$	0.8258***	0.8065***	0.7875***	0.8539***	0.8084***	0.8008***
$\beta_{1,2}$	0.0002	0.0033	-0.0059	-0.0040	0.0056	0.0038
$\beta_{2,1}$	-0.0040	-0.0065	-0.0046	-0.0039	-0.0083	-0.0043
$\beta_{2,2}$	0.9625***	0.9617***	0.9606***	0.9610***	0.9654***	0.9617***
$\rho_{2,1}$	0.1583***	0.1047***	0.1023***	0.1348***	0.1051***	0.1254***
$\alpha_{1,1} + \beta_{1,1}$	0.9940	0.9821	0.9971	0.9891	0.9516	0.9793
$\alpha_{2,2} + \beta_{2,2}$	0.9957	0.9968	0.9967	0.9959	0.9951	0.9963
Log L	-12901.378	-13143.427	-13643.611	-13564.287	-13277.631	-13536.110
AIC	7.552	7.694	7.986	7.940	7.772	7.923
SBC	7.583	7.724	8.017	7.970	7.803	7.954
Diagnostics of Standardised Residuals						
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Industrials**
Q(20)	39.757***	44.888***	55.876***	31.200*	35.993**	54.537***
Q²(20)	17.915	19.914	23.236	10.331	32.602**	10.748
Q(10)	19.025**	19.359**	30.625***	18.133*	18.803**	26.612***
Q²(10)	3.501	5.178	3.644	3.169	3.413	3.483
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	16.280	16.217	16.427	16.580	16.950	16.205
Q²(20)	12.808	13.061	12.963	12.866	12.232	13.009
Q(10)	5.511	5.626	5.718	5.679	5.953	5.451
Q²(10)	9.841	9.728	9.663	9.772	9.815	9.743

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3423.

Table A5: The VAR-GARCH model estimates for stock sector indices of petroleum importing countries.

Panel A: Australia	**Basic Materials & Brent**	**Consumer Cyclicals & Brent**	**Consumer Non-Cyclicals & Brent**	**Energy & Brent**	**Financials & Brent**	**Healthcare & Brent**	**Industrials & Brent**	**Telecommunications Services & Brent**	**Utilities & Brent**
Mean Equation									
$\mu_{1,0}$	0.0005	0.0069	0.0043	0.0243	0.0286	0.0262	0.0340	0.0362*	0.0219
$\phi_{1,1}$	0.0595***	0.0147	-0.0100	0.0267	0.0235	-0.0433**	0.0449**	0.0184	-0.0368*
$\phi_{1,2}$	0.1281***	0.0390***	0.0331***	0.2316***	0.0391***	0.0235**	0.0507***	0.0110	0.0533***
$\mu_{2,0}$	0.0495**	0.0452	0.0380	0.0496*	0.0411	0.0378	0.0452*	0.0328	0.0383
$\phi_{2,1}$	0.0242*	0.0221	0.0093	0.0235	0.0225	0.0222	0.0152	0.0208	0.0144
$\phi_{2,2}$	0.0101	0.0144	0.0191	0.0110	0.0165	0.0158	0.0155	0.0169	0.0199
Variance Equation									
$c_{1,1}$	0.0683**	0.0194**	0.0249***	0.0717***	0.0155**	0.0312***	0.0299***	0.0763***	0.0152**
$c_{2,2}$	0.0145*	0.0151**	0.0135	0.0144*	0.0127**	0.0175*	0.0162**	0.0180	0.0144**
$\alpha_{1,1}$	0.0833***	0.0606***	0.0581***	0.0883***	0.0726***	0.0529***	0.0604***	0.1001***	0.0567***
$\alpha_{1,2}$	0.0124	0.0073**	0.0090***	0.0149**	0.0054**	0.0069**	0.0088**	0.0044	0.0047
$\alpha_{2,1}$	0.0048	0.0082	0.0089	0.0099**	0.0056	0.0086	0.0072	0.0147	0.0133
$\alpha_{2,2}$	0.0403***	0.0407***	0.0406***	0.0346***	0.0402***	0.0405***	0.0409***	0.0385***	0.0379***
$\beta_{1,1}$	0.8933***	0.9239***	0.9229***	0.8863***	0.9164***	0.9205***	0.9238***	0.8363***	0.9322***
$\beta_{1,2}$	-0.0076	-0.0049	-0.0064**	-0.0052	-0.0035	-0.0027	-0.0075**	0.0087	-0.0026
$\beta_{2,1}$	-0.0051	-0.0089	-0.0066	-0.0083	-0.0034	-0.0122	-0.0088	-0.0166	-0.0116
$\beta_{2,2}$	0.9568***	0.9563***	0.9553***	0.9602***	0.9558***	0.9572***	0.9565***	0.9582***	0.9578***
$\rho_{2,1}$	0.2575***	0.2548***	0.2373***	0.3068***	0.2429***	0.2326***	0.2563***	0.2196***	0.2529***
$\alpha_{1,1} + \beta_{1,1}$	0.9766	0.9846	0.9810	0.9746	0.9890	0.9734	0.9842	0.9364	0.9889
$\alpha_{2,2} + \beta_{2,2}$	0.9971	0.9970	0.9959	0.9948	0.9960	0.9977	0.9974	0.9967	0.9957
Log L	-13889.435	-12765.627	-12763.761	-14029.404	-12759.967	-12821.631	-13093.114	-12971.064	-12900.786
AIC	8.001	7.355	7.354	8.082	7.352	7.387	7.543	7.473	7.433
SBC	8.031	7.385	7.384	8.112	7.382	7.417	7.573	7.503	7.463
Diagnostics of Standardised Residuals									
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Telecommunications Services**	**Utilities**
Q(20)	13.505	17.084	11.201	16.033	15.925	13.515	17.975	16.392	7.410
Q²(20)	25.742	23.013	19.968	17.207	16.892	26.959	35.719**	34.563**	22.809
Q(10)	9.489	9.229	7.065	7.167	10.310	6.357	12.009	7.250	3.910
Q²(10)	19.881**	17.037*	7.545	10.532	10.742	17.804*	25.087***	19.237**	8.264
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	9.086	9.296	9.508	8.326	9.341	9.365	9.109	9.565	9.111
Q²(20)	20.741	20.810	20.923	20.129	20.086	20.488	20.853	21.238	19.546
Q(10)	5.228	5.471	5.561	4.457	5.445	5.541	5.319	5.413	5.123
Q²(10)	10.683	10.612	10.685	10.333	10.376	10.382	10.768	10.743	10.179

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3478.

Panel B: Brazil	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Industrials & Brent	Utilities & Brent
Mean Equation							
$\mu_{1,0}$	0.0192	0.1048***	0.0382	0.0020	0.0366	0.0679**	0.0334
$\phi_{1,1}$	0.0664***	0.1060***	0.0783***	0.0313*	0.1076***	0.0962***	0.0745***
$\phi_{1,2}$	0.0056	-0.0545***	-0.0112	-0.0058	-0.0415**	-0.0319*	-0.0208
$\mu_{2,0}$	0.0448	0.0395	0.0338	0.0509	0.0340	0.0412	0.0373
$\phi_{2,1}$	0.0714***	0.0607***	0.0720***	0.0788***	0.070***	0.0737***	0.064***
$\phi_{2,2}$	-0.0098	-0.0048	-0.0035	-0.0185	-0.0089	-0.0055	0.0005
Variance Equation							
$c_{1,1}$	0.1544***	0.2126***	0.1037***	0.1707***	0.1787***	0.1582***	0.2093***
$c_{2,2}$	0.0232*	0.0182	0.0076	0.0214*	0.0106	0.0132	0.0155
$\alpha_{1,1}$	0.0884***	0.1209***	0.0962***	0.0867***	0.1158***	0.1548***	0.1262***
$\alpha_{1,2}$	0.0089	0.0082	0.0159**	0.0215	0.0193	0.0097	0.0151
$\alpha_{2,1}$	0.0096*	0.0134**	0.0129**	0.0114**	0.0112**	0.0154**	0.016**
$\alpha_{2,2}$	0.0369***	0.0358***	0.0328***	0.0328***	0.0323***	0.0329***	0.0335***
$\beta_{1,1}$	0.8665***	0.8288***	0.8613***	0.8784***	0.8284***	0.7779***	0.8170***
$\beta_{1,2}$	0.0094	0.0034	0.0000	-0.0121	0.0114	0.0252	-0.0056
$\beta_{2,1}$	-0.0111	-0.0128	-0.0079	-0.0125*	-0.0090	-0.0134	-0.0149*
$\beta_{2,2}$	0.9594***	0.9596***	0.9611***	0.9635***	0.9627***	0.9624***	0.9624***
$\rho_{2,1}$	0.2557***	0.2294***	0.2316***	0.3006***	0.2233***	0.2215***	0.2006***
$\alpha_{1,1}+\beta_{1,1}$	0.9550	0.9497	0.9575	0.9650	0.9442	0.9327	0.9432
$\alpha_{2,2}+\beta_{2,2}$	0.9963	0.9954	0.9939	0.9963	0.9951	0.9953	0.9959
Log L	-14275.484	-14164.779	-13720.168	-14384.349	-14250.339	-13821.892	-13853.412
AIC	8.412	8.347	8.085	8.476	8.397	8.145	8.164
SBC	8.443	8.378	8.116	8.507	8.428	8.176	8.195
Diagnostics of Standardised Residuals							
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Industrials**	**Utilities**
Q(20)	16.512	25.100	16.319	16.165	24.991	30.386*	17.605
Q²(20)	14.845	8.741	12.334	7.206	3.773	6.449	5.325
Q(10)	6.162	6.450	8.199	7.377	11.651	13.168	11.176
Q²(10)	5.743	4.494	6.475	4.385	2.015	4.417	3.259
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	11.144	12.575	12.506	12.223	12.490	12.413	13.014
Q²(20)	21.471	21.747	17.975	19.375	18.115	18.639	17.519
Q(10)	6.991	8.088	8.025	7.256	8.086	8.124	7.942
Q²(10)	8.225	8.087	6.734	6.025	6.651	6.823	6.371

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3400.

Panel C: Chile	Consumer Non-Cyclicals & Brent	Financials & Brent	Industrials & Brent	Utilities & Brent
Mean Equation				
$\mu_{1,0}$	0.0223	0.0470**	0.0074	0.0389**
$\phi_{1,1}$	0.1212***	0.1491***	0.1198***	0.1339***
$\phi_{1,2}$	-0.0102	-0.0144	-0.0077	-0.0200**
$\mu_{2,0}$	0.0459	0.0434	0.0417	0.0434
$\phi_{2,1}$	0.0340	0.0354	0.0224	0.0142
$\phi_{2,2}$	0.0049	0.0033	0.0068	0.0084
Variance Equation				
$c_{1,1}$	0.0781*	0.0650***	0.0855**	0.0661***
$c_{2,2}$	0.0218*	0.0199**	0.0192**	0.0175
$\alpha_{1,1}$	0.1296***	0.1613***	0.1200***	0.1254***
$\alpha_{1,2}$	0.0033	0.0011	-0.0009	0.0038
$\alpha_{2,1}$	0.0067	0.0070	0.0011	0.0028
$\alpha_{2,2}$	0.0376***	0.0372***	0.0370***	0.0384***
$\beta_{1,1}$	0.8192***	0.7851***	0.8337***	0.8096***
$\beta_{1,2}$	-0.0001	0.0031	0.0055	0.0018
$\beta_{2,1}$	-0.0138	-0.0130	-0.0047	-0.0069
$\beta_{2,2}$	0.9608***	0.9607***	0.9608***	0.9593***
$\rho_{2,1}$	0.2214***	0.2409***	0.2075***	0.2190***
$\alpha_{1,1} + \beta_{1,1}$	0.9488	0.9464	0.9537	0.9350
$\alpha_{2,2} + \beta_{2,2}$	0.9984	0.9979	0.9979	0.9977
Log L	-12444.076	-12053.632	-12866.454	-12095.330
AIC	7.277	7.049	7.523	7.073
SBC	7.307	7.079	7.554	7.103
Diagnostics of Standardised Residuals				
	Consumer Non-Cyclicals	**Financials**	**Industrials**	**Utilities**
Q(20)	42.275***	29.77*	49.420***	29.394*
Q²(20)	55.686***	90.592***	46.366***	31.455**
Q(10)	15.793	10.062	26.267***	12.839
Q²(10)	6.814	6.871	4.039	12.524
	Brent	**Brent**	**Brent**	**Brent**
Q(20)	12.936	13.258	13.239	13.584
Q²(20)	19.130	19.001	19.511	19.241
Q(10)	8.056	8.383	8.330	8.679
Q²(10)	6.172	5.908	5.877	6.225

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3427.

Panel D: China	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent
Mean Equation								
$\mu_{1,0}$	0.0125	0.0108	0.0369	-0.0087	0.0086	0.0459*	-0.0041	-0.0071
$\phi_{1,1}$	0.0482**	0.0439**	0.0521**	0.0301	0.0206	0.0440**	0.0411**	0.0303
$\phi_{1,2}$	0.0694***	0.0202	0.0093	0.0865***	0.0369**	-0.0011	0.0312	0.0139
$\mu_{2,0}$	0.0366	0.0360	0.0380	0.0353	0.0300	0.0383	0.0340	0.0352
$\phi_{2,1}$	0.0086	0.0111	0.0033	0.0119	0.0031	-0.0013	0.0078	0.0214
$\phi_{2,2}$	0.0195	0.0205	0.0220	0.0194	0.0203	0.0213	0.0204	0.0190
Variance Equation								
$c_{1,1}$	0.0340***	0.0151***	0.0193**	0.0312***	0.0184***	0.0142*	0.0205**	0.0255**
$c_{2,2}$	0.0058	0.0073	0.0062	0.0081	0.0063	0.0064	0.0067	0.0041
$\alpha_{1,1}$	0.0609***	0.0483***	0.0624***	0.0559***	0.0389***	0.0581***	0.0457***	0.0444***
$\alpha_{1,2}$	-0.0009	0.0054	0.0037	0.0004	0.0023	0.0029	0.0013	0.0079
$\alpha_{2,1}$	0.0012	0.0009	-0.0014	0.0049	0.0075	-0.0020	0.0044	0.0003
$\alpha_{2,2}$	0.0353***	0.0360***	0.0356***	0.0351***	0.0329***	0.0360***	0.0345***	0.0353***
$\beta_{1,1}$	0.9337***	0.9509***	0.9339***	0.9406***	0.9609***	0.9412***	0.9508***	0.9513***
$\beta_{1,2}$	-0.0002	-0.0066*	-0.0036	-0.0022	-0.0057**	-0.0036	-0.0024	-0.0085**
$\beta_{2,1}$	0.0023	0.0016	0.0048	-0.0020	-0.0029	0.0052	0.0001	0.0031
$\beta_{2,2}$	0.9601***	0.9607***	0.9606***	0.9603***	0.9615***	0.9603***	0.9605***	0.9610***
$\rho_{2,1}$	0.1035***	0.0814***	0.0691***	0.1207***	0.0732***	0.0510***	0.0810***	0.0738***
$\alpha_{1,1} + \beta_{1,1}$	0.9946	0.9992	0.9963	0.9965	0.9999	0.9993	0.9965	0.9957
$\alpha_{2,2} + \beta_{2,2}$	0.9954	0.9967	0.9962	0.9954	0.9945	0.9964	0.9950	0.9963
Log L	-13814.063	-13497.416	-13362.923	-13968.444	-13639.263	-13352.961	-13473.548	-13819.234
AIC	8.280	8.090	8.010	8.372	8.175	8.004	8.076	8.283
SBC	8.311	8.121	8.041	8.403	8.206	8.035	8.107	8.314
Diagnostics of Standardised Residuals								
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**
Q(20)	39.644***	38.184***	26.250	32.935**	32.05**	44.764***	33.984**	22.813
Q²(20)	11.013	9.101	29.086*	10.184	14.456	15.911	15.575	8.529
Q(10)	24.542***	19.731**	17.766*	16.681*	24.81***	27.473***	18.661**	13.111
Q²(10)	3.365	6.390	16.897	2.743	8.885	9.551	8.533	6.081
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	12.683	12.772	13.000	12.460	12.637	13.026	12.518	12.668
Q²(20)	17.792	18.121	17.900	18.218	18.237	18.380	18.136	18.639
Q(10)	8.140	8.032	8.256	7.890	7.880	8.300	7.997	7.948
Q²(10)	7.402	7.511	7.083	8.028	7.971	7.372	7.892	7.810

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3343.

Panel E: Eurozone	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent	Telecommunications Services & Brent	Utilities & Brent
Mean Equation										
$\mu_{1,0}$	0.0463**	0.0397**	0.0356**	0.0453**	0.0213	0.0451**	0.0509***	0.0326**	0.0140	0.0524***
$\phi_{1,1}$	0.0787***	0.0567***	0.0226	0.0174	0.0793***	0.0093	0.0771***	0.0234	0.0631***	0.0641***
$\phi_{1,2}$	-0.0027	-0.0018	-0.0050	0.0296**	-0.0104	-0.0103	0.0008	-0.0024	-0.0064	0.0016
$\mu_{2,0}$	0.0490*	0.0441*	0.0421	0.0529*	0.0463	0.0418	0.0443	0.0408	0.0453*	0.0458
$\phi_{2,1}$	0.0115	0.0065	0.0237	0.0200	-0.0031	-0.0023	-0.0035	-0.0020	-0.0006	0.0182
$\phi_{2,2}$	0.0158	0.0156	0.0126	0.0105	0.0211	0.0179	0.0192	0.0189	0.0196	0.0107
Variance Equation										
$c_{1,1}$	0.0317***	0.0279***	0.0212***	0.0395***	0.0416***	0.0391***	0.0342***	0.0306***	0.0446***	0.0362***
$c_{2,2}$	0.0209***	0.0197***	0.0173**	0.0235***	0.0190***	0.0213**	0.0188**	0.0161**	0.0254**	0.0181**
$\alpha_{1,1}$	0.0821***	0.0925***	0.0766***	0.0764***	0.1065***	0.0680***	0.0938***	0.0740***	0.0918***	0.0912***
$\alpha_{1,2}$	0.0040	0.0039	0.0018	0.0016	0.0015	0.0033	0.0045*	0.0039*	0.0026	0.0014
$\alpha_{2,1}$	0.0079	0.0054	0.0069	0.0082	0.0064	0.0109	0.0062	0.0025	0.0171*	0.0126
$\alpha_{2,2}$	0.0403***	0.0425***	0.0410***	0.0375***	0.0405***	0.0406***	0.0415***	0.0420***	0.0401***	0.0393***
$\beta_{1,1}$	0.9036***	0.8956***	0.9045***	0.9019***	0.8865***	0.8989***	0.8902***	0.9099***	0.8776***	0.8853***
$\beta_{1,2}$	-0.0045	-0.0044*	-0.0014	-0.0005	-0.0040	-0.0011	-0.0046*	-0.0031	-0.0016	-0.0002
$\beta_{2,1}$	-0.0113	-0.0090	-0.0114	-0.0096	-0.0081	-0.0180	-0.0091	-0.0048	-0.0260*	-0.0153
$\beta_{2,2}$	0.9566***	0.9550***	0.9566***	0.9570***	0.9567***	0.9571***	0.9557***	0.9559***	0.9575***	0.9578***
$\rho_{2,1}$	0.3211***	0.2808***	0.2604***	0.4738***	0.2575***	0.2423***	0.2833***	0.2544***	0.2616***	0.2690***
$\alpha_{1,1} + \beta_{1,1}$	0.9857	0.9881	0.9811	0.9783	0.9930	0.9669	0.9840	0.9840	0.9694	0.9765
$\alpha_{2,2} + \beta_{2,2}$	0.9969	0.9975	0.9976	0.9945	0.9972	0.9977	0.9973	0.9980	0.9976	0.9970
Log L	-12884.833	-12712.580	-12078.392	-12773.920	-13410.721	-12583.595	-12833.229	-13066.556	-12612.392	-12671.381
AIC	7.324	7.227	6.867	7.261	7.623	7.153	7.295	7.428	7.170	7.203
SBC	7.354	7.256	6.896	7.291	7.653	7.183	7.325	7.457	7.199	7.233
Diagnostics of Standardised Residuals										
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**	**Telecommunications Services**	**Utilities**
Q(20)	19.968	23.110	27.846	17.605	21.228	17.240	20.273	15.737	23.738	22.454
$Q^2(20)$	27.723	17.610	24.889	16.655	17.027	29.540*	32.500**	13.020	13.523	22.210
Q(10)	5.561	9.322	8.721	9.113	10.657	8.814	6.865	5.274	15.854	13.853
$Q^2(10)$	10.703	9.124	6.894	8.164	12.851	13.690	7.877	5.994	7.186	8.998
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	13.749	14.132	13.898	13.713	13.686	13.693	13.891	13.974	13.532	13.997
$Q^2(20)$	20.361	19.794	19.256	20.164	19.741	19.801	19.846	19.410	20.449	19.840
Q(10)	7.080	7.328	7.332	7.015	7.017	7.147	7.233	7.276	6.925	7.468
$Q^2(10)$	7.732	7.883	7.611	7.226	7.540	7.734	7.753	7.789	7.876	7.760

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3525.

Panel F: India	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent	Utilities & Brent
Mean Equation									
$\mu_{1,0}$	0.0415*	0.0543**	0.0817***	0.0271	0.0451	0.0504*	0.0450*	0.0744***	0.0055
$\phi_{1,1}$	0.1035***	0.1316***	0.0826***	0.0913***	0.1359***	0.1068***	0.1605***	0.0479***	0.0711***
$\phi_{1,2}$	0.0423***	0.0079	0.0099	0.0274***	-0.0032	0.0109	-0.0017	0.0358***	0.0192*
$\mu_{2,0}$	0.0444	0.0404	0.0425*	0.0392	0.0453	0.0385	0.0444	0.0339	0.0428
$\phi_{2,1}$	0.0323**	0.0171	0.0173	0.0217	0.0125	0.0359	0.0168	0.0603***	0.0105
$\phi_{2,2}$	0.0075	0.0120	0.0091	0.0110	0.0108	0.0083	0.0095	0.0066	0.0114
Variance Equation									
$c_{1,1}$	0.0811***	0.0738**	0.0555**	0.0809**	0.0894***	0.1211***	0.1029***	0.0775***	0.0902***
$c_{2,2}$	0.0128	0.0156	0.0134	0.0088	0.0175*	0.0295*	0.0146	0.0109	0.0078
$\alpha_{1,1}$	0.1064***	0.1002***	0.1052***	0.1085***	0.0908***	0.1093***	0.1200***	0.0958***	0.0945***
$\alpha_{1,2}$	0.0084	0.0009	0.0028	-0.0010	0.0042	0.0046	0.0067	0.0055	0.0042
$\alpha_{2,1}$	0.0067	0.0112	0.0106	-0.0013	0.0052	0.0186	0.0030	0.0047	0.0010
$\alpha_{2,2}$	0.0416***	0.0399***	0.0396***	0.0404***	0.0416***	0.0409***	0.0415***	0.0407***	0.0402***
$\beta_{1,1}$	0.8709***	0.8673***	0.8605***	0.8706***	0.8932***	0.8157***	0.8585***	0.8738***	0.8836***
$\beta_{1,2}$	-0.0065	0.0026	0.0027	0.0011	-0.0057	0.0043	-0.0052	-0.0043	-0.0040
$\beta_{2,1}$	-0.0056	-0.0111	-0.0098	0.0027	-0.0056	-0.0287	-0.0031	-0.0023	0.0008
$\beta_{2,2}$	0.9552***	0.9569***	0.9573***	0.9568***	0.9553***	0.9577***	0.9557***	0.9556***	0.9569***
$\rho_{2,1}$	0.1726***	0.1499***	0.1590***	0.1211***	0.1470***	0.1560***	0.1492***	0.1395***	0.1432***
$\alpha_{1,1} + \beta_{1,1}$	0.9773	0.9675	0.9657	0.9791	0.9840	0.9250	0.9784	0.9696	0.9782
$\alpha_{2,2} + \beta_{2,2}$	0.9968	0.9968	0.9969	0.9972	0.9969	0.9986	0.9973	0.9962	0.9970
Log L	-13500.154	-13094.171	-12752.003	-13518.196	-14015.447	-12823.204	-13828.786	-13175.226	-13649.242
AIC	7.963	7.724	7.522	7.974	8.267	7.564	8.157	7.772	8.051
SBC	7.994	7.755	7.553	8.004	8.297	7.595	8.187	7.802	8.082
Diagnostics of Standardised Residuals									
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**	**Utilities**
Q(20)	34.327**	24.590	19.718	37.176**	32.094**	31.354*	31.230*	18.784	52.842***
$Q^2(20)$	8.901	7.213	14.657	10.845	8.207	17.686	12.935	21.203	9.550
Q(10)	17.197*	9.910	7.996	17.693*	16.833*	7.118	21.759**	6.654	29.269***
$Q^2(10)$	4.394	3.706	9.002	5.993	6.301	11.829	8.096	4.680	3.729
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	16.451	17.490	17.733	16.623	17.074	17.165	16.927	16.913	17.137
$Q^2(20)$	26.223	26.876	26.944	23.986	26.591	27.143	25.401	24.695	23.827
Q(10)	7.063	7.642	7.843	7.189	7.503	7.422	7.235	7.377	7.457
$Q^2(10)$	12.781	12.918	12.981	11.257	13.183	14.035	12.319	11.407	11.212

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3397.

Panel G: Indonesia	Basic Materials & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent
Mean Equation				
$\mu_{1,0}$	0.0201	0.0315	0.0383	0.0595**
$\phi_{1,1}$	0.0798***	0.0468**	0.0744***	0.1135***
$\phi_{1,2}$	0.0848***	0.0657***	0.1293***	0.0322**
$\mu_{2,0}$	0.0404	0.0411	0.0485*	0.0435
$\phi_{2,1}$	0.0172	0.0067	0.0141	0.0045
$\phi_{2,2}$	0.0256	0.0270*	0.0247	0.0288
Variance Equation				
$c_{1,1}$	0.1249***	0.0673**	0.2351***	0.1179**
$c_{2,2}$	0.0118	0.0103	0.0092	0.0141
$\alpha_{1,1}$	0.1271***	0.1141***	0.1501***	0.1539***
$\alpha_{1,2}$	0.0179	0.0060	0.0193	0.0054
$\alpha_{2,1}$	0.0005	-0.0017	-0.0012	-0.0024
$\alpha_{2,2}$	0.0409***	0.0394***	0.0404***	0.0409***
$\beta_{1,1}$	0.8415***	0.8607***	0.7997***	0.8158***
$\beta_{1,2}$	-0.0081	0.0019	-0.0060	0.0005
$\beta_{2,1}$	0.0010	0.0038	0.0028	0.0022
$\beta_{2,2}$	0.9554***	0.9570***	0.9561***	0.9566***
$\rho_{2,1}$	0.1505***	0.1594***	0.1813***	0.1382***
$\alpha_{1,1} + \beta_{1,1}$	0.9686	0.9748	0.9498	0.9697
$\alpha_{2,2} + \beta_{2,2}$	0.9963	0.9964	0.9966	0.9975
Log L	-13790.439	-13299.462	-14002.599	-13454.416
AIC	8.268	7.974	8.395	8.067
SBC	8.299	8.005	8.426	8.098
Diagnostics of Standardised Residuals				
	Basic Materials	**Consumer Non-Cyclicals**	**Energy**	**Financials**
Q(20)	25.703	23.815	34.721**	16.162
Q²(20)	19.418	13.370	12.017	11.240
Q(10)	8.387	6.704	16.131*	8.211
Q²(10)	0.591	4.413	5.330	6.522
	Brent	**Brent**	**Brent**	**Brent**
Q(20)	22.036	22.357	22.202	22.014
Q²(20)	7.753	7.546	7.564	7.574
Q(10)	7.633	7.945	7.614	7.617
Q²(10)	6.195	5.902	5.964	5.861

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3342.

Panel H: Israel	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Industrials & Brent	Technology & Brent
Mean Equation						
$\mu_{1,0}$	0.0380*	0.0301	0.0600	0.0424**	0.0476**	0.0442**
$\phi_{1,1}$	0.1378***	0.1149***	0.0887***	0.1168***	0.1238***	0.0590***
$\phi_{1,2}$	-0.0013	-0.0081	-0.0173	0.0001	-0.0061	0.0035
$\mu_{2,0}$	0.0337	0.0417	0.0388	0.0384	0.0357	0.0351
$\phi_{2,1}$	0.0386*	0.0257	0.0039	0.0298	0.0306	0.0280
$\phi_{2,2}$	0.0087	0.0047	0.0095	0.0067	0.0080	0.0063
Variance Equation						
$c_{1,1}$	0.0412**	0.0526***	0.0504***	0.0263**	0.0403***	0.0367***
$c_{2,2}$	0.0127	0.0268**	0.0181**	0.0157**	0.0191*	0.0122
$\alpha_{1,1}$	0.1017***	0.0994***	0.1110***	0.1039***	0.0879***	0.0785***
$\alpha_{1,2}$	-0.0014	-0.0009	-0.0006	-0.0017	-0.0054**	0.0027
$\alpha_{2,1}$	0.0245*	0.0398***	0.0268**	0.0252**	0.0406***	0.0110
$\alpha_{2,2}$	0.0341***	0.0363***	0.0356***	0.0340***	0.0299***	0.0367***
$\beta_{1,1}$	0.8783***	0.8781***	0.8705***	0.8871***	0.8956***	0.9047***
$\beta_{1,2}$	0.0031	-0.0004	0.0035	0.0020	0.0048	-0.0027
$\beta_{2,1}$	-0.0179	-0.0424**	-0.0246*	-0.0210*	-0.0368**	-0.0076
$\beta_{2,2}$	0.9603***	0.9596***	0.9600***	0.9607***	0.9642***	0.9593***
$\rho_{2,1}$	0.1425***	0.1694***	0.1473***	0.1826***	0.1468***	0.1683***
$\alpha_{1,1} + \beta_{1,1}$	0.9800	0.9775	0.9815	0.9910	0.9835	0.9833
$\alpha_{2,2} + \beta_{2,2}$	0.9944	0.9958	0.9956	0.9947	0.9941	0.9960
Log L	-12671.681	-12503.891	-13055.935	-12602.755	-12673.095	-12659.069
AIC	7.539	7.440	7.768	7.498	7.540	7.532
SBC	7.570	7.471	7.799	7.529	7.571	7.563
Diagnostics of Standardised Residuals						
	Consumer Cyclicals	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Industrials**	**Technology**
Q(20)	15.849	21.585	26.746	25.489	20.749	17.905
$Q^2(20)$	20.185	17.945	14.475	24.053	32.552**	23.847
Q(10)	11.583	7.309	10.811	14.551	9.411	3.081
$Q^2(10)$	8.299	7.780	11.072	11.381	19.847**	12.022
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	10.470	10.252	10.506	10.128	9.474	9.955
$Q^2(20)$	21.404	20.481	18.978	21.168	19.394	20.462
Q(10)	5.674	5.168	5.713	5.639	5.058	5.529
$Q^2(10)$	11.212	10.844	9.986	11.103	11.994	10.396

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3368.

Panel I: Japan	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent	Utilities & Brent
Mean Equation								
$\mu_{1,0}$	0.0325	0.0369*	0.0444**	0.0057	0.0446**	0.0455**	0.0089	-0.0022
$\phi_{1,1}$	-0.0652***	-0.1263***	-0.1387***	-0.0307*	-0.1405***	-0.1027***	-0.1010***	-0.0387*
$\phi_{1,2}$	0.1057***	0.0705***	0.0359***	0.0817***	0.0469***	0.0866***	0.0610***	0.0135
$\mu_{2,0}$	0.0346	0.0345	0.0305	0.0288	0.0312	0.0365	0.0372	0.0256
$\phi_{2,1}$	0.0143	0.0135	0.0041	0.0128	0.0099	0.0038	0.0119	-0.0045
$\phi_{2,2}$	0.0258	0.0268	0.0290	0.0296	0.0300	0.0268	0.0262	0.0322
Variance Equation								
$c_{1,1}$	0.0950***	0.0550***	0.0942***	0.029**	0.0589**	0.0632***	0.0469***	0.0374**
$c_{2,2}$	0.0028	0.0031	0.0076	0.0021	0.0051	0.0032	0.0050	0.0111
$\alpha_{1,1}$	0.1227***	0.1231***	0.1474***	0.0667***	0.1054***	0.1254***	0.0904***	0.0855***
$\alpha_{1,2}$	0.0112**	0.007**	0.0057	0.0042	0.0103***	0.0088**	0.0091**	0.0091**
$\alpha_{2,1}$	-0.0014	-0.0028	0.0131**	-0.0020	0.0030	-0.0025	-0.0057	0.0055
$\alpha_{2,2}$	0.0350***	0.0353***	0.0350***	0.0355***	0.0350***	0.0350***	0.0370***	0.0352***
$\beta_{1,1}$	0.8175***	0.8310***	0.7336***	0.9207***	0.8415***	0.8288***	0.8783***	0.9002***
$\beta_{1,2}$	0.0009	0.0025	0.0129	-0.0016	-0.0021	0.0002	-0.0031	-0.0075**
$\beta_{2,1}$	0.0075	0.0102	-0.0084	0.0086	0.0029	0.0096	0.0109	-0.0056
$\beta_{2,2}$	0.9617***	0.9613***	0.9624***	0.9603***	0.9623***	0.9614***	0.9600***	0.9632***
$\rho_{2,1}$	0.1281***	0.1009***	0.0584***	0.1036***	0.0577***	0.1340***	0.1145***	0.0164
$\alpha_{1,1} + \beta_{1,1}$	0.9402	0.9541	0.8810	0.9874	0.9469	0.9542	0.9687	0.9856
$\alpha_{2,2} + \beta_{2,2}$	0.9966	0.9966	0.9974	0.9958	0.9973	0.9964	0.9970	0.9983
Log L	-12996.147	-12630.577	-12183.742	-13287.830	-12436.949	-12735.017	-12870.941	-12965.722
AIC	7.721	7.504	7.239	7.894	7.389	7.566	7.646	7.703
SBC	7.752	7.535	7.270	7.925	7.420	7.597	7.677	7.733
Diagnostics of Standardised Residuals								
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Financials**	**Healthcare**	**Industrials**	**Technology**	**Utilities**
Q(20)	29.934*	24.651	23.749	15.738	17.325	30.931*	17.957	12.803
Q²(20)	18.344	20.071	35.464**	29.478*	20.991	21.907	23.541	111.562***
Q(10)	9.429	7.571	8.237	6.295	10.235	8.333	4.661	5.127
Q²(10)	13.868	14.416	28.026***	21.859**	14.349	15.362	19.096**	102.725***
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	13.863	13.814	13.569	13.618	13.385	13.968	13.803	12.974
Q²(20)	19.324	19.001	18.427	19.486	19.443	19.315	20.153	19.842
Q(10)	8.663	8.575	8.214	8.439	8.211	8.801	8.709	7.985
Q²(10)	5.534	5.473	5.393	5.494	5.600	5.473	5.839	5.714

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3373.

Panel J: New Zealand	Consumer Cyclicals & Brent	Financials & Brent	Industrials & Brent
Mean Equation			
$\mu_{1,0}$	0.0021	0.0191	0.0416***
$\phi_{1,1}$	0.0620***	0.0003	0.0674***
$\phi_{1,2}$	0.0288***	0.0203***	0.0211**
$\mu_{2,0}$	0.0373	0.0353	0.0335
$\phi_{2,1}$	0.0141	0.0070	0.0283
$\phi_{2,2}$	0.0165	0.0179	0.0156
Variance Equation			
$c_{1,1}$	0.0293	0.0097*	0.0186
$c_{2,2}$	0.0124	0.0124	0.0118
$\alpha_{1,1}$	0.0541***	0.0542***	0.0461*
$\alpha_{1,2}$	0.0011	-0.0009	0.0003
$\alpha_{2,1}$	0.0114	0.0104	0.0214
$\alpha_{2,2}$	0.0397***	0.0397***	0.0388***
$\beta_{1,1}$	0.9125***	0.9271***	0.9337***
$\beta_{1,2}$	0.0031	0.0038	0.0018
$\beta_{2,1}$	-0.0063	-0.0004	-0.0144
$\beta_{2,2}$	0.9560***	0.9547***	0.9564***
$\rho_{2,1}$	0.2083***	0.2255***	0.1958***
$\alpha_{1,1} + \beta_{1,1}$	0.9666	0.9814	0.9798
$\alpha_{2,2} + \beta_{2,2}$	0.9956	0.9944	0.9952
Log L	-12386.093	-11936.064	-12341.018
AIC	7.184	6.923	7.158
SBC	7.214	6.954	7.188
Diagnostics of Standardised Residuals			
	Consumer Cyclicals	**Financials**	**Industrials**
Q(20)	33.999**	12.249	13.648
Q²(20)	24.251	30.691*	33.706**
Q(10)	15.021	6.539	3.754
Q²(10)	15.290	13.162	26.236***
	Brent	**Brent**	**Brent**
Q(20)	9.197	9.341	9.088
Q²(20)	28.807*	29.425*	29.730*
Q(10)	5.430	5.545	5.506
Q²(10)	12.693	12.547	13.128

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3455.

Panel K: Pakistan	Basic Materials & Brent	Consumer Cyclicals & Brent	Energy & Brent	Financials & Brent	Utilities & Brent
Mean Equation					
$\mu_{1,0}$	0.0657***	0.0532**	0.0718***	0.0472***	0.0156
$\phi_{1,1}$	0.1857***	0.2392***	0.1502***	0.1868***	0.0638***
$\phi_{1,2}$	0.0111	0.0219**	0.0538***	0.0108	0.0201
$\mu_{2,0}$	0.0420	0.0433	0.0433	0.0374	0.0400
$\phi_{2,1}$	-0.0141	0.0068	-0.0246	0.0104	0.0025
$\phi_{2,2}$	0.0295*	0.0259	0.0257	0.0259	0.0277
Variance Equation					
$c_{1,1}$	0.1354***	0.1269***	0.1012***	0.1064***	0.1277***
$c_{2,2}$	0.0390**	0.0396**	0.0180	0.0229*	0.0351*
$\alpha_{1,1}$	0.1630***	0.1548***	0.1441***	0.1661***	0.1451***
$\alpha_{1,2}$	0.0098*	0.0040**	0.0056**	0.0039**	0.0108
$\alpha_{2,1}$	0.0374**	0.0415***	0.0137	0.0123	0.0223
$\alpha_{2,2}$	0.0496***	0.0447***	0.0439***	0.0423***	0.0492***
$\beta_{1,1}$	0.7768***	0.7830***	0.8211***	0.7921***	0.7831***
$\beta_{1,2}$	-0.0126***	-0.0073**	-0.0098***	-0.0086***	-0.0081
$\beta_{2,1}$	-0.0451**	-0.0520**	-0.0121	-0.0169	-0.0330
$\beta_{2,2}$	0.9461***	0.9514***	0.9519***	0.9552***	0.9484***
$\rho_{2,1}$	0.0320*	0.0570***	0.0715***	0.0343**	0.0390**
$\alpha_{1,1} + \beta_{1,1}$	0.9398	0.9379	0.9653	0.9582	0.9282
$\alpha_{2,2} + \beta_{2,2}$	0.9957	0.9961	0.9958	0.9976	0.9977
Log L	-12569.781	-12398.688	-12713.789	-12397.734	-12566.955
AIC	7.415	7.314	7.500	7.314	7.413
SBC	7.446	7.345	7.530	7.344	7.444
Diagnostics of Standardised Residuals					
	Basic Materials	**Consumer Cyclicals**	**Energy**	**Financials**	**Utilities**
Q(20)	28.895*	50.040***	20.512	63.680***	26.277
Q²(20)	20.231	16.843	11.021	19.291	12.758
Q(10)	16.292*	40.787***	13.638	47.089***	19.424**
Q²(10)	12.285	10.386	5.979	14.511	10.003
	Brent	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	10.722	10.662	11.210	10.690	10.321
Q²(20)	19.900	19.277	19.357	21.038	20.654
Q(10)	5.303	5.461	5.892	5.114	5.028
Q²(10)	5.133	4.660	4.563	5.697	6.136

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3397.

Panel L: South Africa	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Financials & Brent	Industrials & Brent	Technology & Brent	Telecommunications Services & Brent
Mean Equation							
$\mu_{1,0}$	-0.0127	0.0226	0.0349	0.0375	0.0076	0.0510*	0.0049
$\phi_{1,1}$	0.0590***	0.1016***	0.0816***	0.0791***	0.0947***	0.0479***	0.0195
$\phi_{1,2}$	0.0150	-0.0096	-0.0121	-0.0076	0.0057	0.0033	0.0068
$\mu_{2,0}$	0.0400	0.0384	0.0363	0.0398	0.0355	0.0385	0.0351
$\phi_{2,1}$	0.0490***	0.0487**	0.0567***	0.0390	0.0526**	0.0427**	0.0331*
$\phi_{2,2}$	0.0014	0.0092	0.0074	0.0087	0.0070	0.0084	0.0136
Variance Equation							
$c_{1,1}$	0.0563**	0.0529***	0.0477**	0.0448***	0.0417**	0.1085***	0.0729***
$c_{2,2}$	0.0130	0.0102	0.0087	0.0122	0.0072	0.0077	0.0061
$\alpha_{1,1}$	0.0609***	0.0649***	0.0634***	0.0788***	0.0645***	0.0973***	0.0660***
$\alpha_{1,2}$	0.0087	0.0021	0.0033	0.0037	0.0013	0.0012	0.0081
$\alpha_{2,1}$	0.0059	0.0054	0.0092	0.0065	0.0048	0.0039	0.0060
$\alpha_{2,2}$	0.0387***	0.0395***	0.0383***	0.0387***	0.0384***	0.0383***	0.0369***
$\beta_{1,1}$	0.8986***	0.8903***	0.8898***	0.8660***	0.8959***	0.8373***	0.8884***
$\beta_{1,2}$	0.0071	0.0085	0.0082	0.0142	0.0105	0.0122*	0.0066
$\beta_{2,1}$	-0.0022	-0.0005	0.0005	-0.0042	0.0054	-0.0007	0.0006
$\beta_{2,2}$	0.9556***	0.9558***	0.9550***	0.9575***	0.9545***	0.9583***	0.9573***
$\rho_{2,1}$	0.3574***	0.2654***	0.2664***	0.2620***	0.2735***	0.2509***	0.2410***
$\alpha_{1,1}+\beta_{1,1}$	0.9595	0.9552	0.9533	0.9448	0.9604	0.9347	0.9544
$\alpha_{2,2}+\beta_{2,2}$	0.9943	0.9953	0.9933	0.9962	0.9929	0.9966	0.9942
Log L	-13376.023	-12956.747	-12848.035	-12875.455	-13011.002	-13214.895	-13498.241
AIC	7.803	7.558	7.495	7.511	7.590	7.709	7.874
SBC	7.833	7.589	7.525	7.541	7.620	7.739	7.904
Diagnostics of Standardised Residuals							
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Financials**	**Industrials**	**Technology**	**Telecommunications Services**
Q(20)	15.200	11.098	19.714	12.802	15.874	18.624	15.124
$Q^2(20)$	18.958	22.685	23.483	17.455	16.637	17.815	20.373
Q(10)	12.146	5.851	14.784	7.216	7.711	13.420	4.888
$Q^2(10)$	7.231	14.817	10.422	9.084	6.921	5.283	5.563
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	12.425	12.731	12.926	12.868	12.267	12.619	12.466
$Q^2(20)$	17.013	17.601	17.557	16.902	17.731	16.643	17.662
Q(10)	6.382	6.806	6.853	6.913	6.483	6.653	6.538
$Q^2(10)$	8.607	8.732	8.548	8.237	8.743	8.150	8.444

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3435.

Panel M: South Korea	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent
Mean Equation								
$\mu_{1,0}$	0.0453*	0.0217	0.0522**	0.0340	0.0346	0.0279	0.0282	0.0156
$\phi_{1,1}$	0.0318*	0.0147	0.0401**	0.0090	0.0275*	0.0681***	0.0632***	0.0219
$\phi_{1,2}$	0.1002***	0.0710***	0.0574***	0.1465***	0.0982***	0.0395***	0.1154***	0.0557***
$\mu_{2,0}$	0.0429	0.0389	0.0388	0.0399	0.0384	0.0416	0.0438	0.0424
$\phi_{2,1}$	-0.0068	-0.0089	-0.0291	-0.0074	0.0027	0.0024	0.0114	0.0024
$\phi_{2,2}$	0.0247	0.0243	0.0259	0.0236	0.0220	0.0231	0.0222	0.0242
Variance Equation								
$c_{1,1}$	0.0412***	0.0315***	0.0518***	0.0390***	0.0307***	0.0846***	0.0536**	0.0540**
$c_{2,2}$	0.0127*	0.0131*	0.0093	0.0125*	0.0110*	0.0164*	0.0138**	0.0164*
$\alpha_{1,1}$	0.0803***	0.0733***	0.0772***	0.0697***	0.0600***	0.1106***	0.0854***	0.0765***
$\alpha_{1,2}$	0.0090*	0.0044	0.0116**	0.0084	0.0053	0.0235**	0.0090	0.0085*
$\alpha_{2,1}$	0.0100	0.0113	0.0164	0.0101	0.0089*	0.0143**	0.0128**	0.0133*
$\alpha_{2,2}$	0.0364***	0.0370***	0.0360***	0.0349***	0.0361***	0.0381***	0.0344***	0.0371***
$\beta_{1,1}$	0.8938***	0.9070***	0.8795***	0.9140***	0.9292***	0.8422***	0.8914***	0.8972***
$\beta_{1,2}$	-0.0022	-0.0013	-0.0033	-0.0037	-0.0032	-0.0003	-0.0010	-0.0041
$\beta_{2,1}$	-0.0087	-0.0096	-0.0099	-0.0085	-0.0058	-0.0148	-0.0117	-0.0140
$\beta_{2,2}$	0.9599***	0.9592***	0.9589***	0.9607***	0.9589***	0.9591***	0.9614***	0.9597***
$\rho_{2,1}$	0.1726***	0.1539***	0.1263***	0.1870***	0.1511***	0.0905***	0.1690***	0.1390***
$\alpha_{1,1}+\beta_{1,1}$	0.9741	0.9803	0.9567	0.9836	0.9891	0.9528	0.9768	0.9737
$\alpha_{2,2}+\beta_{2,2}$	0.9963	0.9962	0.9949	0.9957	0.9950	0.9972	0.9958	0.9968
Log L	-13125.801	-12830.124	-12753.271	-13569.356	-13637.525	-13669.794	-13639.489	-13242.974
AIC	7.733	7.559	7.514	7.994	8.034	8.053	8.036	7.802
SBC	7.764	7.590	7.545	8.025	8.065	8.084	8.066	7.833
Diagnostics of Standardised Residuals								
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**
Q(20)	22.991	22.458	19.235	13.267	14.455	16.224	24.429	13.183
Q²(20)	16.602	23.167	15.908	24.292	37.981***	13.264	23.454	30.085*
Q(10)	16.097	17.868*	11.051	5.287	9.720	13.123	17.749*	9.076
Q²(10)	10.223	17.141*	9.260	15.006	31.065***	7.507	20.810**	19.005**
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	15.483	15.683	16.147	15.618	15.690	15.247	14.947	15.100
Q²(20)	23.848	24.289	25.040	24.105	24.528	24.247	22.825	24.701
Q(10)	6.777	6.813	6.807	6.782	6.968	6.679	6.430	6.373
Q²(10)	9.478	9.729	10.775	9.633	9.685	9.676	8.782	9.332

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3401.

Panel N: Sweden	Consumer Cyclicals & Brent	Financials & Brent	Industrials & Brent
Mean Equation			
$\mu_{1,0}$	0.0113	0.0302	0.0535**
$\phi_{1,1}$	-0.0094	-0.0277	-0.0402***
$\phi_{1,2}$	0.0072	0.0119	0.0225*
$\mu_{2,0}$	0.0399	0.0412	0.0425
$\phi_{2,1}$	-0.0120	-0.0061	-0.0015
$\phi_{2,2}$	0.0127	0.0121	0.0101
Variance Equation			
$c_{1,1}$	0.0391***	0.0425**	0.0404**
$c_{2,2}$	0.0199**	0.0187***	0.0182**
$\alpha_{1,1}$	0.0786***	0.0829***	0.0797***
$\alpha_{1,2}$	0.0029	0.0022	0.0035
$\alpha_{2,1}$	0.0027	0.0056	0.0041
$\alpha_{2,2}$	0.0398***	0.0384***	0.0400***
$\beta_{1,1}$	0.9047***	0.9051***	0.9079***
$\beta_{1,2}$	-0.0007	-0.0022	-0.0022
$\beta_{2,1}$	-0.0060	-0.0076	-0.0057
$\beta_{2,2}$	0.9583***	0.9592***	0.9575***
$\rho_{2,1}$	0.2788***	0.2781***	0.3020***
$\alpha_{1,1} + \beta_{1,1}$	0.9833	0.9879	0.9876
$\alpha_{2,2} + \beta_{2,2}$	0.9981	0.9977	0.9974
Log L	-13331.073	-13586.984	-13619.071
AIC	7.731	7.880	7.898
SBC	7.762	7.910	7.928
Diagnostics of Standardised Residuals			
	Consumer Cyclicals	**Financials**	**Industrials**
Q(20)	24.477	17.966	25.243
Q²(20)	17.563	26.111	16.253
Q(10)	9.138	7.252	10.465
Q²(10)	10.168	10.885	6.965
	Brent	**Brent**	**Brent**
Q(20)	11.126	11.026	11.164
Q²(20)	16.606	17.285	16.814
Q(10)	5.242	5.184	5.296
Q²(10)	8.505	8.763	8.827

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3455.

Panel O: Taiwan	Basic Materials & Brent	Financials & Brent	Technology & Brent
Mean Equation			
$\mu_{1,0}$	0.0279	0.0258	0.0436**
$\phi_{1,1}$	0.0640***	0.0313	0.0767***
$\phi_{1,2}$	0.0892***	0.0613***	0.0524***
$\mu_{2,0}$	0.0336	0.0328	0.0348
$\phi_{2,1}$	0.0238	0.0134	0.0264
$\phi_{2,2}$	0.0141	0.0153	0.0139
Variance Equation			
$c_{1,1}$	0.0188*	0.0111	0.0230***
$c_{2,2}$	0.0103	0.0092	0.0094
$\alpha_{1,1}$	0.0729***	0.0581***	0.0600***
$\alpha_{1,2}$	0.0013	0.0005	-0.0012
$\alpha_{2,1}$	0.0218*	0.0147	0.0204**
$\alpha_{2,2}$	0.0348***	0.0357***	0.0323***
$\beta_{1,1}$	0.9111***	0.9373***	0.9290***
$\beta_{1,2}$	0.0015	-0.0004	0.0015
$\beta_{2,1}$	-0.0171	-0.0094	-0.0146
$\beta_{2,2}$	0.9611***	0.9597***	0.9626***
$\rho_{2,1}$	0.1604***	0.1406***	0.1415***
$\alpha_{1,1} + \beta_{1,1}$	0.9840	0.9954	0.9890
$\alpha_{2,2} + \beta_{2,2}$	0.9960	0.9955	0.9949
Log L	-12404.115	-12546.784	-12758.960
AIC	7.358	7.443	7.569
SBC	7.389	7.474	7.600
Diagnostics of Standardised Residuals			
	Basic Materials	**Financials**	**Technology**
Q(20)	25.065	24.047	28.451*
Q²(20)	17.194	13.117	18.598
Q(10)	7.184	10.718	8.132
Q²(10)	8.193	8.120	10.156
	Brent	**Brent**	**Brent**
Q(20)	13.227	13.545	12.865
Q²(20)	30.381*	30.725*	29.341*
Q(10)	10.312	10.645	9.941
Q²(10)	6.871	7.655	7.248

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3378.

Panel P: Thailand	Consumer Cyclicals & Brent	Energy & Brent	Financials & Brent	Industrials & Brent
Mean Equation				
$\mu_{1,0}$	0.0688***	0.0796***	0.0542**	0.0589**
$\phi_{1,1}$	0.0465**	0.0293*	0.1200***	0.0613***
$\phi_{1,2}$	0.0182	0.0830***	0.0089	0.0025
$\mu_{2,0}$	0.0378	0.0475*	0.0368	0.0402
$\phi_{2,1}$	0.0125	0.0037	-0.0057	-0.0257
$\phi_{2,2}$	0.0351*	0.0347*	0.0380**	0.0447***
Variance Equation				
$c_{1,1}$	0.1026*	0.1367	0.0399	0.0443
$c_{2,2}$	0.0178*	0.0054	0.0089	0.0058
$\alpha_{1,1}$	0.1378**	0.1912**	0.1500**	0.1316*
$\alpha_{1,2}$	-0.0006	-0.0064	-0.0039	-0.0068
$\alpha_{2,1}$	0.0058	0.0007	-0.0025	-0.0081
$\alpha_{2,2}$	0.0379***	0.0372***	0.0394***	0.0409***
$\beta_{1,1}$	0.8202***	0.7491***	0.8468***	0.8520***
$\beta_{1,2}$	0.0017	0.0299	0.0056	0.0116
$\beta_{2,1}$	-0.0088	0.0051	0.0037	0.0107
$\beta_{2,2}$	0.9603***	0.9573***	0.9583***	0.9566***
$\rho_{2,1}$	0.1345***	0.2318***	0.1425***	0.1298***
$\alpha_{1,1} + \beta_{1,1}$	0.9580	0.9402	0.9967	0.9836
$\alpha_{2,2} + \beta_{2,2}$	0.9982	0.9945	0.9977	0.9976
Log L	-12727.926	-13252.299	-12851.582	-12811.021
AIC	7.591	7.903	7.664	7.640
SBC	7.622	7.934	7.695	7.671
Diagnostics of Standardised Residuals				
	Consumer Cyclicals	**Energy**	**Financials**	**Industrials**
Q(20)	40.890***	34.251**	28.553*	28.026
Q²(20)	24.294	11.036	10.479	8.188
Q(10)	23.349**	21.483**	10.792	19.355**
Q²(10)	11.895	7.783	7.691	4.408
	Brent	**Brent**	**Brent**	**Brent**
Q(20)	22.041	21.474	22.107	21.955
Q²(20)	11.166	11.704	10.452	10.087
Q(10)	12.060	11.335	11.819	11.582
Q²(10)	5.513	5.047	5.046	4.918

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3360.

Panel Q: Turkey	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Financials & Brent	Industrials & Brent
Mean Equation					
$\mu_{1,0}$	0.1181***	0.0855**	0.0936***	0.0771**	0.1084***
$\phi_{1,1}$	0.0702***	0.0969***	0.0812***	0.0733***	0.0676***
$\phi_{1,2}$	0.0117	-0.0091	-0.0124	-0.0169	-0.0131
$\mu_{2,0}$	0.0523*	0.0533**	0.0525*	0.0484*	0.0517*
$\phi_{2,1}$	-0.0015	0.0012	-0.0001	0.0001	-0.0041
$\phi_{2,2}$	0.0260	0.0244	0.0259	0.0226	0.0247
Variance Equation					
$c_{1,1}$	0.3462***	0.2111***	0.2029***	0.2263***	0.2810***
$c_{2,2}$	0.0222*	0.0232**	0.0210**	0.0266***	0.0250**
$\alpha_{1,1}$	0.1881***	0.1741***	0.1599***	0.1193***	0.1690***
$\alpha_{1,2}$	0.0219	0.0206	0.0233**	0.0156	0.0230*
$\alpha_{2,1}$	0.0037	0.0073	0.0043	0.0048	0.0057
$\alpha_{2,2}$	0.0404***	0.0410***	0.0416***	0.0411***	0.0418***
$\beta_{1,1}$	0.7443***	0.7716***	0.7862***	0.8294***	0.7632***
$\beta_{1,2}$	-0.0041	0.0009	-0.0076	0.0006	-0.0065
$\beta_{2,1}$	-0.0055	-0.0099	-0.0064	-0.0078	-0.0084
$\beta_{2,2}$	0.9574***	0.9574***	0.9564***	0.9572***	0.9561***
$\rho_{2,1}$	0.1907***	0.1877***	0.1863***	0.1916***	0.1837***
$\alpha_{1,1} + \beta_{1,1}$	0.9324	0.9456	0.9461	0.9487	0.9322
$\alpha_{2,2} + \beta_{2,2}$	0.9978	0.9984	0.9980	0.9983	0.9979
Log L	-14399.967	-14157.937	-14068.198	-14556.755	-14234.219
AIC	8.343	8.203	8.151	8.434	8.247
SBC	8.373	8.233	8.181	8.464	8.277
Diagnostics of Standardised Residuals					
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Financials**	**Industrials**
Q(20)	27.187	29.321*	21.195	22.632	21.792
Q²(20)	18.817	15.381	17.458	16.356	18.153
Q(10)	17.207*	20.785**	9.342	12.000	11.166
Q²(10)	6.678	4.746	5.763	3.307	6.769
	Brent	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	10.803	10.843	10.744	10.961	10.899
Q²(20)	14.969	15.480	15.105	15.196	15.281
Q(10)	4.044	4.166	4.019	4.261	4.156
Q²(10)	9.238	9.579	9.318	9.564	9.540

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3458.

Panel R: United Kingdom	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Utilities & Brent
Mean Equation								
$\mu_{1,0}$	0.0307	0.0507**	0.0401***	0.0349	0.0419***	0.0491**	0.0569***	0.0203
$\phi_{1,1}$	-0.0150	-0.0020	-0.0234	-0.0065	0.0111	-0.0292	-0.0223	-0.0226
$\phi_{1,2}$	0.0244	0.0033	0.0045	0.0446***	0.0076	0.0009	0.0054	0.0242**
$\mu_{2,0}$	0.0426*	0.0403	0.0370	0.0483	0.0427	0.0338	0.0388	0.0312
$\phi_{2,1}$	0.0269*	0.0194	0.0471*	0.0544**	0.0111	0.0059	0.0121	0.0500*
$\phi_{2,2}$	0.0171	0.0222	0.0173	0.0033	0.0223	0.0242	0.0242	0.0181
Variance Equation								
$c_{1,1}$	0.0253***	0.0327***	0.0366***	0.0336***	0.0349***	0.0743***	0.0371***	0.0630***
$c_{2,2}$	0.0175***	0.0131**	0.0042	0.0180***	0.0138**	-0.0022	0.0106	0.0225
$\alpha_{1,1}$	0.0534***	0.1081***	0.1054***	0.0753***	0.1242***	0.0928***	0.0943***	0.0983***
$\alpha_{1,2}$	0.0030	-0.0022	0.0009	0.0012	-0.0005	0.0047	-0.0010	-0.0010
$\alpha_{2,1}$	0.0056	0.0076	0.0157	0.0126*	0.0065	0.0071	0.0030	0.0417**
$\alpha_{2,2}$	0.0376***	0.0405***	0.0370***	0.0331***	0.0407***	0.0378***	0.0405***	0.0337***
$\beta_{1,1}$	0.9393***	0.8757***	0.8477***	0.9101***	0.8618***	0.8160***	0.8759***	0.8137***
$\beta_{1,2}$	-0.0021	0.0033	0.0044	0.0001	0.0033	0.0075	0.0048	0.018**
$\beta_{2,1}$	-0.0058	-0.0051	-0.0014	-0.0080	-0.0063	0.0144	0.0009	-0.0496
$\beta_{2,2}$	0.9583***	0.9555***	0.9580***	0.9587***	0.9565***	0.9559***	0.9557***	0.9638***
$\rho_{2,1}$	0.3892***	0.2359***	0.2282***	0.4907***	0.2731***	0.2117***	0.2578***	0.2192***
$\alpha_{1,1} + \beta_{1,1}$	0.9927	0.9838	0.9532	0.9854	0.9860	0.9088	0.9701	0.9119
$\alpha_{2,2} + \beta_{2,2}$	0.9959	0.9960	0.9951	0.9918	0.9971	0.9937	0.9962	0.9974
Log L	-13887.625	-12767.692	-12033.950	-12922.383	-13083.415	-12350.995	-12600.452	-12458.520
AIC	8.010	7.364	6.942	7.454	7.546	7.124	7.268	7.186
SBC	8.040	7.395	6.972	7.484	7.576	7.155	7.298	7.216
Diagnostics of Standardised Residuals								
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Utilities**
Q(20)	16.998	23.452	17.569	11.017	23.334	22.561	22.693	14.360
$Q^2(20)$	24.066	20.520	20.655	11.019	29.604*	18.043	16.350	20.546
Q(10)	7.663	19.223**	10.649	5.226	13.816	14.074	17.686*	9.561
$Q^2(10)$	10.120	13.650	4.819	8.035	18.550**	10.880	8.149	11.348
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	12.458	12.547	12.540	12.050	12.637	12.908	12.810	12.224
$Q^2(20)$	13.833	13.119	12.278	14.240	13.824	12.737	12.845	13.531
Q(10)	5.527	5.967	5.907	5.276	5.895	6.133	5.964	5.769
$Q^2(10)$	5.717	5.717	5.823	6.447	5.920	5.712	5.605	5.587

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q^2 represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3474.

Panel S: United States	Basic Materials & Brent	Consumer Cyclicals & Brent	Consumer Non-Cyclicals & Brent	Energy & Brent	Financials & Brent	Healthcare & Brent	Industrials & Brent	Technology & Brent	Telecommunications Services & Brent	Utilities & Brent
Mean Equation										
$\mu_{1,0}$	0.0422**	0.0317**	0.0427***	0.0437*	0.0520***	0.0672***	0.0575***	0.0662***	-0.0026	0.0374***
$\phi_{1,1}$	-0.0146	0.0143	-0.0440***	-0.0288*	-0.0630***	-0.0506**	-0.0253*	-0.0136	0.0014	-0.0237
$\phi_{1,2}$	0.0087	0.0008	0.0002	0.0122	0.0021	-0.0005	0.0057	-0.0020	-0.0165**	0.0051
$\mu_{2,0}$	0.0341	0.0288	0.0279	0.0357	0.0353	0.0282	0.0316	0.0316	0.0347	0.0305
$\phi_{2,1}$	0.1685***	0.1162***	0.1305***	0.2532***	0.0987***	0.0870**	0.1311***	0.1262***	0.0913***	0.1284***
$\phi_{2,2}$	-0.0086	0.0091	0.0138	-0.0790***	0.0106	0.0135	0.0036	0.0045	0.0092	0.0117
Variance Equation										
$c_{1,1}$	0.0297***	0.0208***	0.0199***	0.0353***	0.0216***	0.0208***	0.0266***	0.0308***	0.0796***	0.0183***
$c_{2,2}$	0.0180***	0.0159**	0.0223**	0.0161***	0.0137***	0.0182**	0.0185***	0.0169**	0.0218*	0.0134
$\alpha_{1,1}$	0.0908***	0.0866***	0.1119***	0.0811***	0.1275***	0.0958***	0.0913***	0.0929***	0.1168***	0.0921***
$\alpha_{1,2}$	0.0043*	0.0014	0.0011	0.0054	0.0007	0.0021	0.0037*	0.0068**	-0.0002	0.0027
$\alpha_{2,1}$	0.0279***	0.0315**	0.0901***	0.0203**	0.0205**	0.0479**	0.0310**	0.0292**	0.0209	0.0363**
$\alpha_{2,2}$	0.0365***	0.0361***	0.0376***	0.0304***	0.0364***	0.0377***	0.0386***	0.0384***	0.0397***	0.0378***
$\beta_{1,1}$	0.8911***	0.8981***	0.8547***	0.8980***	0.8647***	0.8740***	0.8873***	0.8805***	0.8443***	0.8785***
$\beta_{1,2}$	-0.0030	-0.0011	-0.0003	0.0041	-0.0006	0.00002	-0.0032	-0.0037	-0.0007	0.0005
$\beta_{2,1}$	-0.0292**	-0.0325*	-0.1056**	-0.0162	-0.0198**	-0.0564**	-0.0345*	-0.0324*	-0.0239	-0.0365
$\beta_{2,2}$	0.9598***	0.9605***	0.9601***	0.9616***	0.9603***	0.9602***	0.9583***	0.9591***	0.9570***	0.9594***
$\rho_{2,1}$	0.2334***	0.1287***	0.0915***	0.4304***	0.1564***	0.0959***	0.1764***	0.1477***	0.1321***	0.1135***
$\alpha_{1,1} + \beta_{1,1}$	0.9819	0.9847	0.9666	0.9791	0.9922	0.9698	0.9786	0.9734	0.9611	0.9706
$\alpha_{2,2} + \beta_{2,2}$	0.9964	0.9966	0.9977	0.9920	0.9967	0.9979	0.9970	0.9975	0.9966	0.9972
Log L	-12629.010	-12281.217	-10987.586	-13304.888	-12442.374	-11628.261	-12101.359	-12457.453	-12702.963	-11730.465
AIC	7.314	7.113	6.365	7.705	7.206	6.735	7.009	7.215	7.357	6.794
SBC	7.344	7.143	6.395	7.735	7.236	6.765	7.039	7.245	7.387	6.825
Diagnostics of Standardised Residuals										
	Basic Materials	**Consumer Cyclicals**	**Consumer Non-Cyclicals**	**Energy**	**Financials**	**Healthcare**	**Industrials**	**Technology**	**Telecommunications Services**	**Utilities**
Q(20)	23.992	22.096	16.006	27.645	35.620**	21.015	32.084**	16.713	22.294	11.289
Q²(20)	20.875	26.688	23.320	37.023**	20.627	35.202**	20.193	24.676	6.888	26.466
Q(10)	8.454	14.155	10.424	11.388	19.180**	11.398	15.584	9.340	8.189	7.795
Q²(10)	12.919	15.510	17.110*	25.273***	8.881	28.878***	12.493	9.999	3.218	22.269**
	Brent	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**	**Brent**
Q(20)	26.064	26.022	27.485	26.560	26.346	27.072	25.623	25.316	25.844	26.466
Q²(20)	15.772	16.346	17.804	15.937	16.261	16.570	17.022	17.546	16.554	15.739
Q(10)	4.831	5.014	5.525	4.540	5.475	5.452	5.260	5.175	5.761	5.777
Q²(10)	4.671	4.896	5.412	3.657	4.652	4.854	4.830	5.304	4.657	4.546

Notes: Models are estimated by the QMLE method using the BFGS algorithm and robust standard errors. The order of variables is stock sector indices (1) and Brent crude petroleum (2). μ refers to constant terms and φ represents autoregressive terms in the mean equation. For instance, the coefficient $\phi_{1,2}$ captures the impact of one period lag petroleum returns on current period returns of stock sector indices. c refers to constant terms, α and β represent ARCH and GARCH terms, respectively, in the variance equation. For example, the coefficients $\alpha_{1,2}$ and $\beta_{1,2}$ show transmission of innovations or shocks and volatilities from petroleum to stock sector indices. ρ denotes constant conditional correlations. Q and Q² represent Ljung-Box statistics of standardised residuals and squared standardised residuals, respectively. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively. The number of observations per sector index is 3460.