The impact of crude oil prices on Chinese stock markets and selected sectors: evidence from the VAR-DCC-GARCH model

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Abstract

The interaction between oil and stock market returns is one of the most important relationships that have a significant influence on the economy of any country all over the world. Therefore, this paper investigates the impact of crude oil prices on the Chinese stock market and selected industries by using the VAR-DCC-GARCH model over the period from December 26, 2001, to April 30, 2019. The empirical results show that the impact of Brent crude oil prices on the Shanghai Composite Index and selected industries is significant. However, there are some variations in these relationships and the degree of influence on each differs during different sample periods. Brent crude oil prices exert substantial influence on some specific industries, like mining, chemical, nonferrous metals, and steel. Whereas, the volatility spillover effect of Brent crude oil prices is stronger within the mining, chemical, steel, nonferrous metal, building materials, building decoration, electrical equipment, electrical equipment, textile and garment, light manufacturing, public utility, and transportation industries than within other industries. When oil prices change abruptly, the risk of spillover impacts of oil prices on stock markets will also increase. In conclusion, the impact of Brent crude oil prices on the Chinese stock market is generally positive. Furthermore, the subsequent volatility of Chinese stock market prices will, in turn, influence the volatility spillover of Brent crude oil prices on the indexes. The result is an ongoing back and forth of changes in price volatilities.

Keywords Oil prices · Chinese stock markets · Impulse response · VAR-DCC-GARCH

Introduction

Crude oil, as crucial energy in all industries, is regarded as the blood of modern industry; therefore, it has a significant impact on major macroeconomic factors of the worldwide economy. In recent decades, the price of crude oil fluctuates significantly, and this influences the companies’ operational costs, and therefore, their sales. In fact, Brent crude oil price, one of the benchmarks of the global crude oil pricing system, has demonstrated instability since the twenty-first century. From 2000 to 2008, crude oil prices rose from $73 to $132.3 at most and experienced a steep decline after the subprime loan crisis to $39.95. When the world economy recovered from the crisis, crude oil prices also rose to over $100 in 2011. Nevertheless, in 2016, it fell to 26.68, which is the lowest ever. Until now, the crude oil price has risen to over $70. Consequently, this variation in the oil price affects the asset price and increases the volatility, which has a direct impact on the financial market. Nowadays, more and more individuals and institutions regard crude oil as a financial tool to hedge and increase values, which increase
the volatility of oil price, thus increasing the volatility of the economy of a country, especially the stock market.

Being one of the largest economies in the world, China is not immune to such variation impact. In the last 4 decades, China has witnessed major changes in its economy, and this was accompanied by a revolution in all sectors. One of these sectors is its industrial sector that depends heavily on oil as its sole energy and its dependence on foreign oil reach 70.9%, with year-on-year growth of 2.5%. In fact, China is considered the largest oil import country in the world in 2018. According to China’s customs, China imported 462 million tons of oil in 2018, with year-on-year growth of 10.1%, which indicates 9.24 million barrels of oil each day. Hence, the volatility of oil prices requires deep and comprehensive study since it will lead to great shocks on China’s economy. Sahu et al. (2021) revealed that the rise in crude oil price, GDP, and population density will increase renewable energy use in the short run and in the long run as well. E.-C Hani (2019) examined the asymmetric influence of oil price shocks on the stock markets of GCC countries. The authors concluded that the negative influence of oil prices on the stock markets of Bahrain and Kuwait is more severe than the positive influence. On the other hand, Mohamed and Julien (2009) provided a contradictory view. The study concludes that oil prices share a positive relationship with the Oman, UAE, and Qatar stock markets. However, the stock movement is independent for Kuwait and Bahrain. Other studies, which have explored the asymmetric relationship are Reboredo (2010) and Wen et al. (2019). Moreover, there is another piece of literature that explores the influence of oil price shocks on the stock prices of different industries. For example, Elyasiani et al. (2011) examined the impact of oil price shock on the stock returns of thirteen US industries. The result supports that oil price variations create a systematic asset price risk at the industry level.

The rest of the study is organized as follows: In the next section, we have provided the literature review. The “Data and methodology” section covers the methodology. The “Data selection and summary statistics” section offers data selection and summary statistics, while the “Conclusion and policy implications” section concludes the study with some policy implications, whereas references are given at the end of the study.

**Literature review**

Since the 1980s, researchers and scholars have conducted many studies that observe the association between oil price and stock returns. Some went further and tried to see the causal and dynamic relationship between the two variables. The studies are focused on both oil-importing and oil-exporting countries. (Alhayki 2014; Bouoiyour et al. 2017; Mokni and Youssef 2019). The subsequent section provides a comprehensive review of the nexus between crude oil prices and stock markets returns.

One of the pioneering papers by Jones and Kaul (1996) examined the dynamic nexus between oil prices shocks and stock markets performances in four developed economies using the cash flow dividend model. The study concludes that oil price fluctuations influence firms’ cash flows, which reduce their profitability and thus create a direct influence on the stock market of the USA and Canada. However, oil price volatility has no significant influence on the stock market performances of Japan and the UK. Similarly, Park and Ratti (2008) investigated the causal relationship between oil prices and stock market performances in oil-importing and oil-exporting countries. The author concludes that oil prices directly impact the stock market performances of the USA and 12 European countries. Inversely, the study also concludes that oil prices positively influence the stock markets of oil-exporting countries. Jiang and Kong (2021) found the positive one-way spillover effect of international crude oil returns on China’s energy stock returns. Yousaf et al. (2021) revealed a positive causal effect from Brazil and Mexico’s stock price changes to the oil market during the global financial crisis. Using the VECM method, Alzyoud (2018) supported the above findings and concluded a positive association between oil prices and Canadian stock market performances. Roberto et al. (2017) further strengthen the above findings and confirm a direct association between oil prices and stock market performances of oil-exporting countries. However, the authors further added that the positive association remains the same even for the oil-importing countries. They reiterated that there is no distinction between oil-exporting and importing economies. On the other hand, a study conducted by Filis et al. (2011) on the stock markets performances of oil-importing and exporting countries negated the above findings. The authors concluded that oil prices have an adverse impact on the stock markets of both the oil importing and exporting countries.

In continuation to the above studies, which have only assessed the symmetric impact of oil prices on the stock markets, there are other studies that have explored both the symmetric and asymmetric relationships. Narayan and Sharma (2011) examined the impact of oil prices on 560 US firms. The results highlight that oil prices impact firms’ share performance differently based on their locations. The authors also conclude that out of the 14 sectors, only 5 sector share returns are affected by sectorial regimes. Likewise, Mohanty et al. (2014) studied the influence of oil price shock on six major US industries. They concluded that oil price shocks have a significant negative influence on the allied industries. The oil price shock is more severe during the global economic crisis specifically during the COVID-19...
Data and methodology

In order to analyze how stock markets, react confronted with the volatility of oil prices we use the DCC-GARCH model to explore the dynamic correlation between oil prices and stock markets in China. VAR is a useful approach to link the macroeconomic variables such as exchange rate, inflation, global oil prices, and output. The VAR has a number of advantages, and it helps to identify the structural shocks through a Cholesky decomposition of innovations. The effects of global oil price shocks to other macroeconomic variables on domestic inflation would also be investigated under a VAR framework. As is well known, time-varying correlations are often estimated with multivariate GARCH models that are linear in squares and cross products of returns. A new model—the dynamic conditional correlation (DCC) is proposed by Engle (2002). The DCC is a standard multivariate volatility model. Primarily, it is based on closing prices. In this study, we have jointly used the VAR–DCC-GARCH model. The main advantage of this model is that it is more robust in terms of non-normal errors. It also incorporates the presence of outliers, heterogeneity, and skewness in the dependent variable. Numerous studies have confirmed that when the VAR-DCC-GARCH model is applied, it gives the best results when analyzing the dynamic correlation between oil prices and stock markets.

The DCC-GARCH model assumes that residual term obeys the t-distribution for the sake of describing the peak and fat tails of financial assets’ time series. To estimate the dynamic conditional coefficient of association, we need first to estimate the conditional variance of each market’s return, which is then divided by residual and to obtain a standard residual series. Eventually, we use the series to estimate the dynamic conditional coefficient of association. The equations are as follows:

\[ r_t | \Omega_{t-1} \sim N(0, H_t) \]  
\[ H_t = D_t R_t D_t \]  
\[ h_{ij,t} = \omega_i + \sum_{j=1}^{p} \phi_i e_{ij,t-p}^2 + \sum_{j=1}^{q} \psi_j h_{ij,t-q} \]  

where \( r_t \) is the return, \( \Omega_{t-1} \) is the information set known, \( H_t \) is conditional covariance matrix; \( D_t \) conditional standard deviation diagonal matrix, that is \( D_t = \text{diag}(q_{11,t}^{-1/2}, \ldots, q_{kk,t}^{-1/2}) \), \( h_{ij,t} \) is the conditional variance computed by the GARCH model, \( \phi_i \) is residual squared coefficient lagged \( p \) order, and \( \psi_j \) is the conditional variance coefficient lagged \( q \) order, among which \( \phi_i \geq 0, \psi_j \geq 0, \) and \( \sum_{j=1}^{p} \phi_j + \sum_{j=1}^{q} \psi_j < 1 \).

\[ R_t = \text{diag}(q_{11,t}^{-1/2}, \ldots, q_{kk,t}^{-1/2})Q_t \text{diag}(q_{11,t}^{-1/2}, \ldots, q_{kk,t}^{-1/2}) \]  
\[ Q_t = \left( 1 - \sum_{m=1}^{M} \alpha_m \sum_{n=1}^{N} \beta_n \right) \bar{Q}_t + \alpha_m \epsilon_{t-m} \epsilon_{t-m}^\prime + \sum_{n=1}^{N} \beta_n Q_{t-n} \]  

where \( R_t \) is dynamic correlation coefficient matrix, \( q_{11,t} \) is the conditional covariance standardized by residual, \( Q_t \) is covariance matrix, \( \epsilon_{t-m} \) is the standardized residual lagged \( m \) orders, \( \alpha_m \) is the coefficient of residual squared, \( \beta_n \) is the conditional variance coefficient, \( \alpha_m \geq 0, \beta_n \geq 0, \) and \( \alpha_m + \beta_n < 1 \). In DCC-GARCH (1,1), the dynamic conditional coefficient between two financial variables is

\[ \rho_{12,t} = \frac{(1 - \alpha - \beta)q_{11,t} + \alpha q_{12,t-1} + \beta q_{12,t-1}}{\sqrt{((1 - \alpha - \beta)q_{11,t} + \alpha q_{12,t-1} + \beta q_{12,t-1})(1 - \alpha - \beta)q_{22,t} + \alpha q_{21,t-1} + \beta q_{21,t-1})}} \]
Conditional dynamic coefficient denotes the degree of risk spillover, the larger \( \rho_{12,t} \) is, the large the degree of risk spillover.

**Data selection and summary statistics**

For the sake of examining the impact of crude oil prices on China’s stock market, this paper uses Brent crude oil spot prices and Shanghai Composite Index to establish the model. As for the selection criteria, we used all industries listed in the Shenwan primary industry as it represents the stock performance of each industry in China’s stock market.

The industry indexes include mining, chemical, steel, nonferrous metal (NM), building materials (BM), building decoration (BD), electrical equipment (EE), mechanical equipment (ME), national defense and military industry (NDMI), automobile, household appliances (HA), textile and garment (TG), light manufacturing (LM), commercial trade (CT), AFAF (agriculture, forestry, animal husbandry, and fishery), food and beverage (FB), leisure service (LS), real estate (RE), electronic engineering (EEng), computer, media, communication, bank, non-bank financial institutions (NBFI), and comprehensive firms (CF).

The data is obtained from China’s data provider company Wind Information for the period from December 26, 2001, to April 30, 2019, on a daily basis.

Figure 1 below shows the historical trend of the Shanghai Composite Index and Brent crude oil. It is obvious that the two variables are moving almost in the same direction.

Figure 2 shows the daily return of the Shanghai Index, Brent crude oil, and the industry indexes.

Figure 1 demonstrates the volatility trends of oil prices and stock markets, from which we may discover that there exist phenomena of volatility clustering in all of these markets, and for the sake of accurately describing volatility, we are about to utilize the GARCH model, and the graphical presentation in Fig. 2 shows the volatility in Shanghai Composite Index, Brent crude oil and SW industry index.

With the data we obtain, to calculate the return of oil and stock indexes, we use the following formula:

\[
R(t) = \ln(P_t) - \ln(P_{t-1})
\]  

\( R(t) \) is the return of either stock index or oil prices, \( P_t \) is the price of oil or stock index in the period of \( t \), and \( P_{t-1} \) is the price of oil or stock index in the period of \( t - 1 \).

The result of descriptive statistics is as follows.

Tables 1 and 2 present the descriptive statistics for all variables over the selected sample period. The results show that Shanghai Composite Index has a higher mean than Brent oil price. Among industries, MB has the highest mean while TG has the lowest. With the exception of Brent crude oil, bank, and NBFI, all variables have negative skewness. Besides, the Kurtosis for all variables exceeds 3, so this rejects the hypothesis of normality for all variables.

Before establishing a VAR model, a unit root test must be carried out. After processing the data, the result is can be seen in Table 3 and Fig. 3.

Our data variables are stationary as the results of both Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) are significant. In other words, all variables pass the unit root test and the VAR model can be established in the following procedure.

To test the asymmetric influence of oil price on Shanghai Composite index, we used a vector error autoregressive model (VAR). Table 4 presents the results of this model.
Oil prices proved to have a significant impact on approximately one-third of the sample industries. Their...

From Table 5, we can see that Brent (−1) has a significant impact on the Shanghai Composite Index and most industry indexes, especially on mining, chemical, nonferrous metal, and steel, with a significant level of 99%.

The Granger causality is shown as follows.

From Table 6, we can see that it is safe to conclude that all factors in this model are interlinked to each other, and they influence each other, we may continue constructing our model.

Figure 4 shows the impulse responses of the Asian stock market to oil prices, from which we can come to some significant conclusions. As there are 30 impulse responses, we only present some typical graphs and summarize the common characteristics. Other responses will be shown in the Appendix.

To begin with, according to all the responses, we can see that when the oil prices offer stock indexes a positive impact, the stock indexes always go up, only that the degree of the impact to each stock index is different from that of others. Besides, after going up in the first 3 periods, the impulse response heads down to zero eventually at the 4th period. Last but not least, the degrees of responses are different, and they can be shown in the following table.
In accordance with Table 7, the impulse responses of the indexes can be divided into two different levels, 0–0.1 and 0–0.004, from which we may conclude that the impact of Brent crude oil on different industries is different. Additionally, the impulse response of Brent crude oil on SH is relatively minor, while on the other hand, the impulse response of Brent crude oil on Mining is significantly bigger, which demonstrates that compared to the market index, Brent crude oil exerts more influence on some certain industries and the trend of the conditional dynamic coefficients can be seen in Fig. 5.

### Table 1: Descriptive statistics of the return on stock indexes and oil prices (1)

| Measure | SH | BRENT | AFAF | AUTOMOBILE | BANK | BD | BM | CF |
|---------|----|-------|------|------------|------|----|----|----|
| Mean    | 0.000155 | 0.000311 | 0.000289 | 0.000298 | 0.000383 | 0.000194 | 0.000294 | 0.00016 |
| Median  | 0.000579 | 0.000684 | 0.001159 | 0.00077 | −0.0003 | 0.00055 | 0.001096 | 0.001345 |
| Maximum | 0.090343 | 0.228873 | 0.091739 | 0.089601 | 0.095507 | 0.109509 | 0.090304 | 0.088185 |
| Minimum | −0.09256 | −0.1791 | −0.09614 | −0.09784 | −0.10506 | −0.09584 | −0.10019 | −0.09742 |
| Std. Dev | 0.016252 | 0.022085 | 0.020285 | 0.020175 | 0.019217 | 0.019014 | 0.020574 | 0.020219 |
| Skewness | −0.352 | 0.074 | −0.499 | −0.426 | 0.155 | −0.316 | −0.454 | −0.661 |
| Kurtosis | 7.409548 | 9.515887 | 5.765256 | 5.94259 | 6.94625 | 6.401264 | 5.742 | 5.698 |
| Jarque-Bera | 3406.837 | 7256.781 | 1476.484 | 1603.321 | 2676.94 | 2044.804 | 1425.612 | 1542.515 |
| Probability | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### Table 2: Descriptive statistics of the return on stock indexes and oil prices (2)

| Measure | LM | LS | MB | ME | Media | Mining | NBFI |
|---------|----|----|----|----|-------|--------|------|
| Mean    | 0.00016 | 0.000372 | 0.000424 | 0.000269 | 0.000219 | 0.000154 | 0.00035 |
| Median  | 0.001314 | 0.001035 | 0.000802 | 0.000863 | 0.001114 | 0.001098 | 0.000519 |
| Maximum | 0.093824 | 0.093275 | 0.088667 | 0.092758 | 0.094623 | 0.094198 | 0.089164 |
| Minimum | −0.10019 | −0.09799 | −0.0911 | −0.09928 | −0.09504 | −0.09315 | −0.09441 |
| Std. Dev | 0.018974 | 0.020195 | 0.018702 | 0.018955 | 0.019339 | 0.019243 | 0.019207 |
| Skewness | −0.69505 | −0.4362 | −0.47033 | −0.53008 | −0.38895 | −0.12952 | 0.079665 |
| Kurtosis | 6.567574 | 5.871343 | 6.052966 | 5.944562 | 5.119423 | 5.118572 | 5.118572 |
| Jarque-Bera | 2504.413 | 1538.471 | 1743.431 | 1673.209 | 870.7529 | 1310.323 | 1136.33 |
| Probability | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Measure | NDMI | NM | PU | RE | STEEL | TG | Transportation |
|---------|------|----|----|----|-------|----|----------------|
| Mean    | 0.000323 | 0.000207 | 0.000145 | 0.000304 | 0.000159 | 0.000190 | 0.000184 |
| Median  | 0.001201 | 0.000735 | 0.000673 | 0.000521 | 0.000654 | 0.001059 | 0.000516 |
| Maximum | 0.159342 | 0.094662 | 0.086193 | 0.094049 | 0.094429 | 0.089343 | 0.09496 |
| Minimum | −0.1023 | −0.10129 | −0.09813 | −0.09754 | −0.09685 | −0.09699 | −0.10051 |
| Std. Dev | 0.023331 | 0.022894 | 0.017394 | 0.021091 | 0.020248 | 0.01962 | 0.018124 |
| Skewness | −0.30052 | −0.31168 | −0.55079 | −0.32815 | −0.30992 | −0.69907 | −0.49559 |
| Kurtosis | 6.088365 | 5.318375 | 6.93456 | 5.686111 | 6.020319 | 6.660138 | 6.961215 |
| Jarque-Bera | 1691.12 | 981.2086 | 2851.934 | 1290.627 | 1624.03 | 2622.527 | 2848.417 |
| Probability | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
The average and variance of the conditional dynamic coefficients are as follows:

To conclude from Table 8, firstly, the average of the conditional dynamic coefficients fall into (0.38, 0.11), and the variance of them are almost of the same level (in (0.005, 0.009) and are mostly approximately 0.007), from which we may see that the volatility spillover of Brent crude oil on Chinese stock market is stable in every industry. Secondly, from the numbers, the volatility spillover of Brent crude oil on every industry is different and the spillovers are larger on mining, chemical, steel, NM, BM, BD, EE, ME, TG, LM, PU, and transportation (bigger than 0.0641). Thirdly, for most of the time, the coefficients are positive, and from 2008 to 2007 and 2008 to 2012, oil prices fell dramatically, leading to the coefficient to drop sharply, and when oil prices started to rise, the coefficient began to increase as well, which demonstrates that when oil prices change fiercely, the risk spillover of oil prices to Chinese stock market will also increase. Last but not least, the impact of Brent crude oil on the Chinese stock market is mostly positive, and the volatility of the Chinese stock market will influence the volatility spillover of Brent crude oil on the indexes. With regard to the details, interestingly, most of the coefficients fluctuate around 0.3 and seldomly fall under 0, meaning that there is the same limit of influence of Brent crude oil exerting to every index.

Conclusion and policy implications

To begin with, the impact of Brent crude oil on the Shanghai Composite Index and every industry is significant, especially on mining, chemical, nonferrous metal, and steel, with a significant level of 99%. To be exact, confronted with the impulse of Brent oil price, the response of Shanghai Index and SW industry indexes increase first, and the degree of response decreases slowly in the next period, and eventually head down to zero fast in the third period. Apparently, facing the volatility of oil price, Shanghai Index and SW Industry indexes react almost the same; however, the degree of the influence on each index is different. That is, compared to the market index, Brent crude oil exerts more influence on certain industries.

This can also be seen from the result of the DCC-GARCH model, which shows the dynamic correlation coefficients of oil to the Chinese stock market and SW industry indexes. According to the result, the volatility spillover of Brent crude oil on the Chinese stock market is stable in every industry, and the spillovers are larger on mining, chemical, steel, NM, BM, BD, EE, ME, TG, LM, PU, and transportation. When oil prices change fiercely, the risk spillover of oil prices to stock markets will also increase. Last but not least, the impact of Brent crude oil on the Chinese stock market is mostly positive and the volatility of the Chinese stock market will influence the volatility spillover of Brent crude oil on the indexes. This paper first uses Brent crude oil prices, Shanghai Composite Index, and SW industry indexes to establish a VAR
model to explore the connections among them and analyze the impulse responses of Brent crude oil on the indexes, and then a DCC-GARCH model is constructed to investigate the volatility spillover effect of Brent crude oil on the indexes. These are the key findings:

- The impact of Brent crude oil on the Shanghai Composite Index and every industry is significant.
- Confronted with the impulse of Brent oil price, the response of Shanghai Index and SW industry indexes increase first, and the degree of response decreases slowly in the next period, and eventually head down to zero fast in the third period.
- Facing the volatility of oil price, Shanghai Index and SW industry indexes responded identically; however, the degree of influence on each index varies. Hence, compared to the market index, Brent crude oil exerts more influence on certain industries, like mining, chemical, nonferrous metal, and steel.
- The volatility spillover of Brent crude oil on the Chinese stock market is stable in every industry, while the spillovers are larger on mining, chemical, steel, nonferrous metal, building materials, building decoration, electrical equipment, electrical equipment, textile and garment, light manufacturing, public utility, and transportation. When oil prices change fiercely, the risk spillover of oil prices to stock markets will also increase.
- The impact of Brent crude oil on the Chinese stock market is mostly positive, and the volatility of the Chinese stock market will influence the volatility spillover of Brent crude oil on the indexes.

Several policy implications can be drawn from this analysis. Owing to the fact that oil prices have a significant impact

### Table 4 Estimation of the VAR part (1)

| Series      | Brent (−1) $\sigma^2$ | Brent (−2) $\sigma^2$ | $t$     |
|-------------|-----------------------|-----------------------|---------|
| Brent       | 0.004536              | −0.01584              | [0.28645] 0.018174 −0.016  [1.13581] |
| SH          | 0.037534              | −0.01162              | [3.23061] 0.001999 0.01174  [0.10210] |
| AFAF        | 0.022708              | −0.01443              | [1.57353] 0.013861 −0.01458 [0.95055] |
| Automobile  | 0.009664              | −0.01438              | [0.67213] −0.00566 −0.01453 −0.38936 |
| Bank        | 0.025458              | −0.01371              | [1.85737] 0.009453 −0.01385 [0.68253] |
| BD          | 0.029624              | −0.01357              | [2.18281] 0.01406 −0.01371 [1.02532] |
| BM          | 0.035509              | −0.01468              | [2.41844] 0.01109 −0.01484 [0.74750] |
| CF          | 0.02348               | −0.01437              | [1.63632] 0.012685 −0.01452 [0.87347] |
| Chemical    | 0.035214              | −0.01317              | [2.67485] 0.00218 0.0133 [0.16387] |
| Communication | 0.033429          | −0.01445              | [2.31847] 0.009178 0.0146 [0.62876] |
| Computer    | 0.015458              | −0.01555              | [0.99382] 0.009361 0.01572 [0.59564] |
| CT          | 0.016467              | −0.01333              | [1.23567] 0.014063 −0.01347 [1.04434] |
| EE          | 0.025                | −0.01379              | [1.81284] 0.012267 −0.01393 [0.88032] |
| EENG        | 0.020583              | −0.01516              | [1.35784] 0.017232 −0.01532 [1.12498] |
| FB          | 0.00893               | −0.01241              | [0.71977] 0.001726 −0.01254 [0.13770] |
| HA          | 0.016154              | −0.01369              | [1.17979] 0.002603 −0.01384 [0.18817] |
| LM          | 0.019017              | −0.01358              | [1.40078] 0.009099 −0.01372 [0.66331] |
| LS          | 0.022042              | −0.01442              | [1.52884] 0.032112 −0.01457 [2.20429] |
| MB          | 0.009438              | −0.01285              | [0.73429] 0.007676 −0.01299 [1.06252] |
| ME          | 0.026974              | −0.0139               | [1.94011] 0.001632 −0.01405 [0.11615] |
| Media       | 0.026425              | −0.01582              | [1.67080] 0.014631 −0.01598 [0.91551] |
| Mining      | 0.099061              | −0.01549              | [6.39443] −0.00054 −0.01565 [0.03465] |
| NBFI        | 0.036254              | −0.01738              | [2.08648] 0.014184 −0.01756 [0.65409] |
| NDMI        | 0.017798              | −0.01666              | [1.06842] 0.011442 −0.01683 [0.67976] |
| NM          | 0.071411              | −0.01629              | [4.38367] −0.0165 −0.01646 [1.00259] |
| PU          | 0.019634              | −0.01243              | [1.57918] 0.008102 −0.01256 [0.64940] |
| RE          | 0.031814              | −0.01509              | [2.10862] 0.010831 −0.01525 [0.71046] |
| Steel       | 0.041795              | −0.01446              | [2.89025] 0.003341 −0.01461 [0.22866] |
| TG          | 0.025012              | −0.01395              | [1.79320] 0.011142 −0.01409 [0.79053] |
| Transportation | 0.019955        | −0.01295              | [1.54126] 0.001091 −0.01308 [0.08340] |

Notes: the null hypothesis of statistical tests are rejected at 10% (*), 5% (**), and 1% (***) levels.
### Table 5  Estimation of the VAR part (2)

| Series          | Brent   | SH      | BRENTH | SH   |
|-----------------|---------|---------|--------|------|
| Brent(−1)       | 0.004536 | 0.037534 | 0.009949 | 0.039561 |
|                 | −0.01584 | −0.01162 | −0.03986 | −0.02925 |
|                 | [0.28645] | [3.23061] | [0.24958] | [1.35265] |
| Brent(−2)       | 0.018174 | 0.001199 | 0.007778 | 0.01998 |
|                 | −0.016    | −0.01174 | −0.03981 | −0.02921 |
|                 | [1.13581] | [0.10210] | [0.19538] | [0.68407] |
| SH(−1)          | −0.117477 | −0.058834 | 0.036644 | −0.02287 |
|                 | −0.12076  | −0.0886  | −0.06857 | −0.0503  |
|                 | [−0.97283] | [−0.66407] | [0.53444] | [−0.45452] |
| SH(−2)          | 0.122212  | 0.03551  | 0.042738 | 0.059108 |
|                 | −0.12147  | −0.08912 | −0.06874 | −0.05043 |
|                 | [1.00612] | [−0.39847] | [0.62178] | [1.17210] |
| AFAF(−1)        | 0.056528  | 0.047595 | 0.01139  | −0.05676 |
|                 | −0.0413   | −0.0303  | −0.03778 | −0.02772 |
|                 | [1.36886] | [1.57092] | [−0.30153] | [−2.04797] |
| AFAF(−2)        | −0.039388 | −0.121399 | −0.01618 | 0.003142 |
|                 | −0.04142  | −0.03039 | −0.0377  | −0.02766 |
|                 | [−0.95085] | [−3.99454] | [−0.42924] | [0.11362] |
| Automobile(−1)  | 0.088709  | −0.006409 | 0.05248  | −0.01669 |
|                 | −0.04601  | −0.03375 | −0.05224 | −0.03833 |
|                 | [1.92822]** | [−0.18988] | [−1.00456] | [−0.43544] |
| Automobile(−2)  | 0.042541  | −0.007273 | 0.009122 | −0.02159 |
|                 | −0.04595  | −0.03371 | −0.05206 | −0.0382  |
|                 | [0.92584] | −0.21573 | [0.17521] | [−0.56531] |
| Bank(−1)        | 0.061788  | 0.053411 | 0.05824  | 0.093796 |
|                 | −0.03874  | −0.02842 | −0.06693 | −0.04911 |
|                 | [1.59499] | [1.87928] | [−0.87008] | [1.91003] |
| Bank(−2)        | −0.002669 | 0.020539 | −0.23062 | 0.034604 |
|                 | −0.03869  | −0.02839 | −0.06685 | −0.04905 |
|                 | [−0.06898] | [0.72354] | [−3.44977] | [0.70552] |
| BD(−1)          | 0.015844  | −0.028045 | 0.046944 | 0.004677 |
|                 | 0.04816   | −0.03533 | −0.03709 | −0.02721 |
|                 | [0.32902] | [−0.79380] | [1.26553] | [0.17184] |
| BD(−2)          | 0.053616  | 0.020674 | 0.001869 | 0.002131 |
|                 | −0.04813  | −0.03531 | −0.03709 | −0.02721 |
|                 | [1.11388] | [0.58542] | [0.05040] | [0.07831] |
| BM(−1)          | 0.038895  | 0.023266 | 0.033055 | −0.01867 |
|                 | 0.04583   | −0.03362 | −0.03481 | −0.02554 |
|                 | [−0.84873] | [0.69200] | [0.94970] | [−0.73121] |
| BM(−2)          | −0.078546 | 0.009095 | −0.06183 | −0.03429 |
|                 | 0.04579   | −0.03359 | −0.03471 | −0.02546 |
|                 | [−1.71538] | [2.70737] | [−1.78133]** | [−1.34646] |
| CF(−1)          | −0.005164 | −0.079023 | −0.02867 | 0.040576 |
|                 | 0.06205   | 0.04553  | 0.02736  | −0.02008 |
|                 | [−0.8322] | [−1.73578] | [−1.04771] | [2.02108] |
| CF(−2)          | −0.061579 | 0.019951 | −0.06888 | 0.005551 |
|                 | −0.06187  | −0.04539 | −0.0273  | −0.02003 |
|                 | [−0.99535] | [0.43956] | [−2.52320]** | [0.27717] |
| Chemical(−1)    | 0.123581  | −0.078407 | 0.048009 | 0.000161 |
|                 | −0.07392  | −0.05423 | −0.02735 | −0.02006 |
|                 | [1.67188] | [−1.44580] | [1.75559]** | [0.00804] |
on the Chinese stock market and all industries, correspond-ent policies should be drawn up to cope with the upcoming impact of the recent fluctuation of Brent crude oil prices. According to our findings, when oil prices fluctuate signifi-cantly, the stock markets will fluctuate correspondingly, and the Shanghai stock markets’ reaction will be great as well. Therefore, actions should be taken to cope with the risk spillover to these markets.

For the first part, financial supervision bureaus of all regions should monitor stock markets closely and prevent systematic risks when confronted with comparatively dra-matic risks, stabilizing domestic financial orders. For the

| Series                | Brent | SH   | NDMI(−2) | SH   | BRENT | SH   |
|-----------------------|-------|------|----------|------|-------|------|
| Chemical(−2)          | 0.018631 | 0.064203 | −0.05414 | −0.02733 | 0.023055 | 0.005462 |
|                       | [0.25246] | [1.18579] | [0.84345] | [0.27237] |
| Communication(−1)    | 0.034552 | 0.011141 | −0.02659 | −0.03397 | 0.038485 | 0.007836 |
|                       | [0.95349] | [0.42934] | [0.99627] | [0.31438] |
| Communication(−2)    | −0.056499 | −0.053473 | −0.05469 | −0.03976 | 0.058817 | 0.011784 |
|                       | [−1.56465] | [−2.01845] | [1.73142] | [0.47281] |
| Computer(−1)         | −0.029028 | 0.016323 | −0.03624 | −0.02659 | −0.0575 | −0.04219 |
|                       | [−0.96511] | [0.45720] | [−0.76760] | [−0.47579] |
| Computer(−2)         | 0.043335 | 0.061233 | −0.0357 | −0.05731 | 0.01833 | −0.00461 |
|                       | [−0.59651] | [1.17509] | [0.31984] | [−0.10965] |
| CT(−1)               | 0.002478 | 0.051542 | −0.06392 | −0.04689 | −0.03173 | 0.021233 |
|                       | [0.03877] | [1.09912] | [−0.88929] | [0.81113] |
| CT(−2)               | 0.063844 | 0.009635 | RE(−2) | 0.039495 | −0.05331 | −0.02631 |
|                       | [1.00413] | [0.20656] | [1.10738] | [−0.09793] |
| EE(−1)               | −0.070581 | −0.068939 | Steel(−1) | −0.02221 | −0.05357 | −0.02618 |
|                       | [−1.32397] | [−1.76261] | [−0.61932] | [−0.29823] |
| EE(−2)               | 0.115667 | 0.014431 | Steel(−2) | −0.03524 | −0.03584 | −0.0263 |
|                       | [0.50337] | [0.3916] | [−0.03916] | [−0.0263] |
| EENG(−1)             | 0.014106 | 0.052816 | TG(−1) | −0.04799 | 0.00337 |
|                       | [0.23147] | [1.18123] | [0.70558] | [0.06753] |
| EENG(−2)             | −0.001589 | −0.04669 | TG(−2) | −0.06464 | −0.05384 | −0.0263 |
|                       | [−0.2609] | [−1.04480] | [−0.95231] | [−1.70604] |
| FB(−1)               | 0.010125 | 0.013175 | Transportation(−1) | −0.03318 | −0.02273 |
|                       | [0.26579] | [0.47142] | [−0.57421] | [−0.53617] |
| FB(−2)               | 0.007894 | −0.002354 | Transportation(−2) | 0.034229 | −0.01506 |
|                       | [0.20731] | [−0.08426] | [0.74702] | [−0.35477] |
| C                    | 0.000291 | 7.89E−05 | −0.00035 | −0.00025 | [0.83960] | [0.31034] |

Notes: the null hypothesis of statistical tests are rejected at 10% (*), 5% (**) and 1% (***) levels
Table 6  Granger causality

| Dependent variable | AFAF | Automobile | Bank | BD | BM  | Brent | CF | HA |
|--------------------|------|------------|------|----|-----|-------|----|----|
| Prob               | 0.0004 | 0.0001 | 0.0000 | 0.0002 | 0.0036 | 0.0613 | 0.0001 | 0.0000 |
| Prob               | 0.0037 | 0.0001 | 0.0020 | 0.0003 | 0.0010 | 0.0014 | 0.0002 | 0.0002 |
| Dependent variable | NDMI | LM  | LS  | MB | ME  | Media | Mining |
| Prob               | 0.0059 | 0.0000 | 0.0021 | 0.0000 | 0.0003 | 0.0020 | 0.0000 |
| Dependent variable | NM   | PU  | RE  | SH | Steel | TG | Transportation |
| Prob               | 0.0000 | 0.0018 | 0.0054 | 0.0004 | 0.0005 | 0.0000 | 0.0008 |

Fig. 4  Impulse response of stock indexes to crude oil price

![Response of SH to BRENT](image1)

![Response of MINING to BRENT](image2)

![Response of CHEMICAL to BRENT](image3)

![Response of NM to BRENT](image4)

![Response of TRANSPORTATION to BRENT](image5)

![Response of STEEL to BRENT](image6)

Table 7  Degree of responses

| Response | Indexes |
|----------|---------|
| 0–0.1    | AFAF, automobile, BM, CF, chemical, computer, EEing, LM, LS, ME, media, mining, NBFI, NDMI, NM, RE, TG |
| 0–0.004  | Bank, BD, communication, CT, EE, FB, HA, MB, PU, SH, steel, transportation |
second, investors of all markets should take into account the risk of spillover of oil to stock markets to prevent potential loss. When the volatility of oil becomes exceedingly high, those who invest in relevant assets or relevant industries should change tactics to avoid losses. What is more, when oil price fluctuates drastically, it is suggested that investors...
might seek opportunities in those sectors that are not so
influenced by the oil price. When the oil price is experi-
encing steady growth, one can invest in some sectors highly
related to the oil price. Last but not least, investments should
be considered to promote the development of new energies
to reduce our dependence on crude oil so that we will suffer
from less impact from the volatility of oil.

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ture review, and methodology (25%); Farhan Ahmed: literature review,
data analysis, and drafting (25%); Zaynab Albayki: data, methodology,
reviewing, and policy recommendations (25%); Amir Aijaz Syed:
analysis, conclusion, and reviewing (25%).

Data availability The data used in this study can be provided by the
corresponding author on reasonable request.

Declarations

Ethics approval All the sources have been cited appropriately, and
there is no such issue during this study.

Consent to participate All the authors will participate in the review
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References

Al Janabi MA, Hatemi-J A, Irandoust M (2010) An empirical inves-
tigation of the informational efficiency of the GCC equity mar-
kets: evidence from bootstrap simulation. Int Rev Financ Anal
19(1):47–54

Alhayki ZJ (2014) The dynamic co-movements between oil and stock
market returns in: the case of GCC countries. J Appl Finance
Bank 4(3):103

Alzyoud H (2018) Dynamics of Canadian oil price and its impact on
exchange rate and stock market. International Journal of Energy
Economics and Policy 8(3):107–114

Apergis N, Miller SM (2009) Do structural oil-market shocks affect
stock prices? Energy Economics 31(4):569–575

Aroui MEH, Rault C (2012) Oil prices and stock markets in GCC
countries: empirical evidence from panel analysis. Int J Financ
Econ 17(3):242–253

Basher SA, Sadorsky P (2006) Oil price risk and emerging stock mar-
kets. Glob Financ J 17(2):224–251

Bouoiyour J, Selmi R, Shahzad SJH, Shahbaz M (2017) Response
of stock returns to oil price shocks: evidence from oil
importing and exporting countries. Journal of Economic
Integration (32)4913–936

Chen KC, Chen S, Wu L (2009) Price causal relations between China
and the world oil markets. Glob Financ J 20(2):107–118

Corbet S, Hou YG, Hu Y, Oxley L (2021) Volatility spillovers dur-
ing market supply shocks: the case of negative oil prices. Resour
Policy 74:102357

Debin DU, Yahua MA (2015) One belt and one road: the grand geo-
strategy of China’s rise. Geogr Res 34(6):1005–1014

Driesprong G, Jacobsen B, Maat B (2008) Striking oil: another puzzle?
J Financ Econ 89(2):307–327

Du L, Yanan H, Wei C (2010) The relationship between oil price
shocks and China’s macro-economy: an empirical analysis.
Energy Policy 38(8):4142–4151

Elyasiani E, Mansur I, Odusami B (2011) Oil price shocks and industry
stock returns. Energy Economics 33(5):966–974

Engle R (2002) Dynamic conditional correlation: A simple class of
multivariate generalized autoregressive conditional heteroske-
dasticity models. Journal of Business & Economic Statistics
20(3):339–350

Faria JR, Mollick AV, Albuquerque PH, León-Ledesma MA (2009)
The effect of oil price on China’s exports. China Econ Rev
20(4):793–805

Filis G, Degiannakis S, Floros C (2011) Dynamic correlation between
stock market and oil prices: the case of oil-importing and oil-
exporting countries. Int Rev Financ Anal 20(3):152–164

Hani E-C (2019) The impact of oil prices on stocks markets: new
evidence during and after the arab spring in gulf cooperation council
economies. International Journal of Energy Economics and Policy
9(4):214–223

Jiang M, Kong D (2021) The impact of international crude oil prices
on energy stock prices: evidence from China. Energy Res Lett
2(4):28133

Table 8 Mean and variance of conditional dynamic coefficients

|       | SH  | Mining | Chemical | Steel | NM  | BM  | BD  | EE  |
|-------|-----|--------|----------|-------|-----|-----|-----|-----|
| Mean  | 0.0846 | 0.1012 | 0.0772   | 0.0676 | 0.0905 | 0.0630 | 0.0723 | 0.0704 |
| Variance | 0.0089 | 0.0090  | 0.0074   | 0.0078 | 0.0088 | 0.0065 | 0.0072 | 0.0062 |
| ME    | NDMI | Automobile | HA      | TG   | LM  | CT  |
| Mean  | 0.0702 | 0.0455  | 0.0518   | 0.0519 | 0.0647 | 0.0646 | 0.0625 |
| Variance | 0.0070 | 0.0065  | 0.0070   | 0.0075 | 0.0071 | 0.0073 | 0.0071 |
| NAF   | FB   | LS     | MB      | PU   | Transportation | RE |
| Mean  | 0.0574 | 0.0546  | 0.0514   | 0.0387 | 0.0721 | 0.0729 | 0.0431 |
| Variance | 0.0072 | 0.0055  | 0.0061   | 0.0070 | 0.0072 | 0.0078 | 0.0074 |
| EEng  | Computer | Media | Communication | Bank | NBFI | CF   |
| Mean  | 0.0540 | 0.0514  | 0.0549   | 0.0694 | 0.0690 | 0.0706 | 0.0617 |
| Variance | 0.0065 | 0.0060  | 0.0057   | 0.0066 | 0.0076 | 0.0081 | 0.0074 |
Jones CM, Kaul G (1996) Oil and the stock markets. J Financ 51(2):463–491
Lin B, Wesseh PK, Appiah MO (2014) Oil price fluctuation, volatility spillover and the Ghanaian equity market: implication for portfolio management and hedging effectiveness. Energy Economics 42:172–182
Mohamed E-HA, Julien F (2009) On the short-term influence of oil price changes on stock markets in GCC countries: linear and non-linear analyses. Economics Bulletin 29(2):795–804
Mohanty S, Nandha M, Habis E, Juhabi E (2014) Oil price risk exposure: the case of the US travel and leisure industry. Energy Economics 41:117–124
Mokni K, Youssef M (2019) Measuring persistence of dependence between crude oil prices and GCC stock markets: a copula approach. Q Rev Econ Finance 72:14–33
Narayan PK, Sharma SS (2011) New evidence on oil price and firm returns. J Bank Finance 35(12):3253–3262
Ozturk I, Arisoy I (2016) An estimation of crude oil import demand in Turkey: evidence from time-varying parameters approach. Energy Policy 99:174–179
Papapetrou E (2001) Oil price shocks, stock market, economic activity and employment in Greece. Energy Economics 23(5):511–532
Park J, Ratti RA (2008) Oil price shocks and stock markets in the US and 13 European countries. Energy Economics 30(5):2587–2608
Peng Z, Martin W (1994) Oil price shocks and policy responses in the post-reform Chinese economy. J Dev Stud 31(1):179–200
Reboredo JC (2010) Nonlinear effects of oil shocks on stock returns: a Markov-switching approach. Appl Econ 42(29):3735–3744
Roberto A, Antonio E, Alba VD (2017) Internationalization of state multilatinas: a multi-case study in the oil sector. Int J Bus 4(4):65–81
Sahu P, Solarin SA, Al-mulali U, Ozturk I (2021) Investigating the asymmetry effects of crude oil price on renewable energy consumption in the United States.
Tang W, Wu L, Zhang Z (2010) Oil price shocks and their short-and long-term effects on the Chinese economy. Energy Economics 32:S3–S14
Wang Y, Wu C, Yang L (2013) Oil price shocks and stock market activities: evidence from oil-importing and oil-exporting countries. J Comp Econ 41(4):1220–1239
Wen F, Xiao J, Xia X, Chen B, Xiao Z, Li J (2019) Oil prices and Chinese stock market: nonlinear causality and volatility persistence. Emerg Mark Financ Trade 55(6):1247–1263
Yousaf I, Ali S, Naveed M, Adeel I (2021) Risk and Return transmissions from crude oil to Latin American stock markets during the crisis: portfolio implications. SAGE Open 11(2):21582440211013800
Yun X, Yoon SM (2019) Impact of oil price change on airline’s stock price and volatility: evidence from China and South Korea. Energy Economics 78:668–679
Zarour BA (2006) Wild oil prices, but brave stock markets! The case of GCC stock markets. Oper Res Int Journal 6(2):145–162

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