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Uncertainty in Oil Prices and Industrial Production in Oil-Exporting Countries: Evidence from Selected Middle East and OECD Nations

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Abstract

Oil constitutes a significant share of the world's total energy consumption. For this reason, any fluctuations in demand, supply, price, or other variables affecting this sector inevitably impact the economies of both oil-producing and oil-consuming countries. Any factor that disrupts the supply or demand for oil and the subsequent market dynamics will, in most cases, lead to a change (increase or decrease) in oil prices. These price changes influence the behavior of energy producers and consumers, as price acts as a key determinant on both the supply and demand sides of the energy market. This study examines the inter-variable, time-varying conditional correlation between global oil prices and the returns of the industrial production index (real GDP) in oil-exporting countries (Iran, Saudi Arabia, and the UAE) and OECD countries. Using monthly data on global oil prices, the performance of the industrial production index in the Middle East and OECD countries from 2000 to 2021, and OxMetrics software, the time-varying conditional correlation between global oil prices and industrial production efficiency in selected countries was analyzed using the CDCC-GARCH method.

The results indicate that the time-varying conditional correlation between global oil prices and real GDP is significant, and changes in final oil prices have caused notable shifts in the dynamic correlation between these variables, manifesting as uncertainty.

Highlights

- This study has utilized GARCH-based methods (Generalized Autoregressive Conditional Heteroskedasticity).
- This study has been conducted among Middle Eastern and OECD countries.
- The results indicate that the time-varying conditional correlation between global oil prices and real GDP is significant.

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1. Introduction

Iran, a developing country and one of the largest oil exporters, has its industrial sector heavily shaped by oil revenues. However, several challenges in the country's industrial sector stem from an unhealthy industrial structure and investment mismanagement, influenced by fluctuations in oil income without adequate coordination among industries. Understanding the effect of oil revenues on Iran's industrial structure is crucial, especially given the country's reliance on oil and the global price volatility. Industrial growth plays a key role in economic development and poverty reduction by effectively utilizing human resources and contributing to infrastructure development. It is vital for balancing foreign payments and fully exploiting the country's economic potential. Oil, as an essential energy source, is strategic for global economies, and rapid price changes in oil markets are major concerns. However, unlike other industries such as textiles, steel, and machine building in developed nations, Iran's oil industry has not led the country's economy. The over-dependence on oil revenues has made Iran's economy vulnerable to external factors, particularly global oil price fluctuations. Failure to meet expected oil export revenues can severely impact the economy, disrupt the implementation of national plans, and create multiple issues across various sectors (Mahdavi Adeli et al., 2012).

Oil, as the largest global energy source, accounts for about 33% of the world's primary energy consumption (Ho & Huang, 2016; van Eyden et al., 2019). Its significant role in the economy has been extensively examined in studies (Sodeyfi & Katircioglu, 2016; Pinho and Madaleno, 2016; Maghrebi et al., 2018; Bildirici & Sonustun, 2018). Over the past two decades, oil prices have exhibited dramatic volatility due to factors such as regional conflicts, OPEC interventions, political tensions, global economic crises, and shifts in oil supply and demand, as highlighted by Oladosu et al. (2018). Oil is a critical commodity for the global economy, but its volatility has increased in recent decades due to various geopolitical factors, such as Middle Eastern conflicts, the 2008–2010 global financial crisis, the Russia-Ukraine dispute, and fluctuating global oil demand and supply (Arouri & Rault, 2011; Mohaddes & Raissi, 2019; Ozcelebi, 2021). The global oil market, valued at over US $1.7 trillion, underscores oil's significance (Nasir et al., 2018). Oil prices have experienced significant fluctuations over the years, each cycle raising concerns for nations due to its impact on economic activities. Cheng et al. (2019) explained that oil price fluctuations affect economies through multiple channels. Rising oil prices directly increase production costs, negatively impacting output. However, they argue that the uncertainty surrounding oil prices (second-moment measure) is even more critical, as it influences companies' expectations regarding future production and investment decisions. Oil price uncertainty, driven by periods of high or low volatility, can occur regardless of whether oil prices are rising or falling. Rahman & Serletis (2012) and Aye et al. (2014) noted that falling oil prices may not necessarily boost manufacturing production, as the increased volatility could counteract the positive effects of the price drop.

The attention of many researchers was directed to the study of the effects of oil shocks on the macroeconomic structure after the shocks of oil price increase in the 1970s and the occurrence of recession in the world economy. Oil price shocks are extremely important because of their impact on the real economy (Lee et al., 2017). These shocks are considered to be one of the main factors affecting macroeconomic variables such as national production growth rate and inflation rate (Kilian, 2008; Taghizadeh-Hesary & Yoshino, 2015), real money supply[1] (Mahdavi Adeli et al., 2012), exchange rate (Amin Z. A. & El-Sakka M. I. T., 2016), the stock market[2] (Cong, et al. 2008) and the trade balance of non-oil countries (Acikalin & Ugurlu 2014).

The factors causing oil price shocks can be generally divided into two main groups of fundamental factors and non-fundamental factors (Pordel & Esfandiari, 2024). According to the theoretical literature, supply and demand[3] are among the fundamental factors and financial markets are among the non-fundamental factors affecting oil prices. Kilian's (2009) study on oil shocks is considered a fundamental study in the field of energy economics, in which, in addition to the global supply of oil and also the global demand for industrial goods for oil, another effective factor on the global price of oil is emphasized, which is specific demand. The oil market, whose nature corresponds to the precautionary demand for oil.

Analyzing oil price dynamics is critical for governments and businesses, as price fluctuations impact economies through multiple channels. Rising oil prices directly increase production costs by raising energy input prices, reducing company profits. Indirectly, higher oil prices lead to inflation, which forces companies to cut production and jobs, increasing unemployment and decreasing GDP. Inflation also prompts monetary authorities to raise interest rates, making borrowing more expensive and reducing investments and production. These higher interest rates negatively affect financial markets, lowering equity and bond valuations, increasing uncertainty, and disrupting economic stability. Thus, volatile oil prices can significantly harm global economies (Zivkov et al, 2020).
The present study investigates the question of "How do industrial production indicators in the studied countries respond to oil price fluctuations? Many past scientific studies have investigated oil price fluctuations on stocks and other macroeconomic variables using various explanatory methods. Also, these studies have not investigated the asymmetric effect, especially regarding the continuation of the effect of oil price fluctuations on industrial production. The innovation of the present research is the use of the CDCC-GARCH method in modeling oil prices and linking industrial production indicators. In the following, theoretical

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[1] The money supply is the sum total of all of the currency and other liquid assets in a country's economy on the date measured.

[2] The stock market consists of exchanges in which stock shares and other financial securities of publicly held companies are bought and sold.

[3] Supply and demand are among the fundamental factors and risks and uncertainties, psychological, political and geopolitical factors, stock exchange and speculation activities in oil financial markets, etc., which cause sudden changes in oil prices are among the non-fundamental factors.

foundations, research background, research method, results and discussion, and general conclusions and suggestions are presented.

2. A Review of the Related Literature

Theoretical studies, such as those by Mork et al. (1994), have explored the links between oil price changes and economic volatility, identifying demand-side and supply-side mechanisms. On the supply side, short-term capital is fixed while labor adjusts. Rising oil prices trigger substitution effects among inputs and reduce oil product supply, regardless of wage flexibility. On the demand side, higher oil prices raise overall price levels unless other prices adjust to neutralize the impact. This interplay often leads to a correlation between oil prices and economic output. Typically, oil-exporting nations benefit from higher incomes, while oil-importing countries face adverse trade effects. Empirical studies have further investigated these dynamics. Hamilton (2003) highlighted that oil price shocks were pivotal in most U.S. post-war recessions, emphasizing their macroeconomic significance. Thiem (2018) corroborates this, noting oil price fluctuations as critical in understanding economic cycles. External factors, such as geopolitical tensions in oil-exporting regions, significantly influence price volatility (Shahbaz et al., 2017). Advanced econometric methods have also been applied to analyze these effects. Pinno & Serletis (2013) used a GARCH-in-Mean VAR model to assess oil price volatility's impact on U.S. industrial production, finding significant effects but failing to capture dynamic correlations or movements. Similarly, Ahmed et al. (2012) employed CGARCH models to examine oil price uncertainty's asymmetric effects. Elder (2020) extended the analysis with multivariate GARCH-in-Mean and structural VAR models, focusing on volatility's role in U.S. industrial production. Despite these contributions, gaps remain in modeling dynamic correlations and interdependence frameworks, particularly for emerging oil-exporting countries. To address this, current research leverages models like DCC-GARCH and GJR-GARCH to analyze these relationships in South America and OECD countries. Cavalcanti & Jalles (2013) also explored oil price uncertainties' effects on inflation in Brazil and the U.S., finding divergent trends due to differing oil import dependencies.

Recent studies by Emenogu et al. (2020), Cai et al. (2020), Yang & Zhou (2020), and Wajdi et al. (2020) reveal new evidence on oil price volatility using GARCH model variants. For instance, Emenogu et al. (2020) analyzed daily stock returns in Total Nigeria with nine GARCH models, showing varying mean-reverting periods for returns. Yang & Zhou (2020), focusing on a brief period in 2018, examined 5-minute oil futures returns (WTI, Brent, and INE) and found stronger linkages between Chinese oil futures and global markets compared to Oman. Boubaker & Raza (2017) applied ARMA-GARCH models to BRICS markets, finding time-varying volatility in all cases. Similarly, Van Eyden et al. (2019) highlighted oil price volatility's significant negative impact on OECD countries' growth from 1870 to 2013. In emerging and industrialized economies, industrial infrastructures are vulnerable to oil price shocks, with weak shock absorption hindering growth (Ali et al., 2019; Shahbaz et al., 2017; Sarwar et al., 2019). Sarwar et al. (2019) compared DCC-GARCH and CDCC-GARCH models, concluding that CDCC-GARCH minimizes risk better. Their results emphasized conditional volatility over volatility spillover in Asian oil-importing countries. Ali et al. (2019) used symmetric and asymmetric GARCH analyses on G7 stock markets, finding that past data and lagged volatility significantly affect current stock market volatility, which surpasses that of oil markets. Rodriguez-Benavides & Lopez-Herrera (2019) found that oil price uncertainty negatively impacted Mexico's economy between 1983 and 2017, with asymmetric effects—output grew after negative oil price shocks but contracted following positive shocks. Katircioglu et al. (2015) explored oil price impacts on OECD economies, discovering stronger effects in the U.S. than Japan. Papaetrou (2009) studied Greece, linking oil prices with employment through industrial production metrics, while Jimenez-Rodriguez & Sanchez (2005) concluded that oil price increases harm economic growth more than price cuts. Although much research has explored oil price volatility's effects on stock markets, the co-movement between oil prices and industrial production remains underexplored.

2.1 Background research

Many researches have been conducted in domestic and foreign studies on the effect of oil price fluctuations on economic activities, some of these studies have been examined below.

Taghinjad Omran et al. (2017) examined the causal links between oil prices, production, industrial production, and inflation in Iran's economy from 1980 to 2017 using a vector autoregression (VAR) model. Their findings revealed that while economic growth is influenced by oil prices and inflation, industrial production did not significantly contribute to growth during this period. Economic growth responded positively to increases in oil prices, though this effect diminished over time. Conversely, inflationary shocks reduced economic growth in the short term and negatively impacted industrial production. In the short run, inflation increased uncertainty in the business environment, leading to slower industrial growth. However, over time, adjustments within the industrial sector and rising prices of industrial goods reversed this trend, ultimately fostering positive growth in industrial production in the long run. Eskandari Atta & Saif (2017) analyzed the challenges posed by oil revenues within the framework of a resistance economy, focusing on the effects of oil price changes on real exchange rate fluctuations, GDP, and deindustrialization using a vector error correction model. Their findings identified three co-accumulation relationships: a 10% increase in oil prices raises the real exchange rate by 5%, reduces GDP by 0.7%, and lowers the ratio of non-tradable to tradable production by 11%. Additionally, the study highlighted indirect effects of oil price fluctuations, which influence the real exchange rate via central bank foreign reserves and government spending. These changes, in turn, impact GDP and industrial productivity, ultimately altering the balance between non-tradable and tradable production.Tak Rousta et al. (2018) studied the effect of national security shocks on the oil price of OPEC countries on Iran's economy. According to the results, OPEC's national security impulses create positive impulses in oil prices for up to three seasons after the oil market developments in 2008, and in this way can have positive effects on Iran's GDP, and therefore these shocks can be a good opportunity for increase the country's foreign exchange income in case of timely detection and action. Khoshkalam Khosrowshahi (2018) examined the symmetric and asymmetric impacts of oil price shocks on Iran's macroeconomic variables during 2018-2019 using a vector error correction model and Granger causality analysis. The study found that, under the symmetric model, oil price shocks positively affected real GDP and liquidity while negatively influencing inflation. In the asymmetric model, positive oil price shocks had positive effects on real GDP and liquidity but a negative effect on inflation. Conversely, negative oil price shocks decreased real GDP and liquidity while increasing inflation. Moreover, the long-term impacts of positive oil price shocks were stronger on real GDP and liquidity but weaker on inflation compared to the effects of negative oil price shocks. Hosseininia & Fatahi (2019) investigated the relationship between crude oil prices and Iran's industrial production using continuous wavelet transform (CWT)[1]. According to the results, the correlation between the oil market and industrial production in long-term time periods is much stronger than in short-term time periods, and it also follows industrial production in low frequencies of the oil market. Lotfalipour et al. (2020) explored the impacts of internal and external shocks on Iran's industrialization, focusing on the industrial sector. Their findings indicate that oil price shocks initially boost industrial production, likely due to expansionary policies; however, this effect becomes neutralized over the long term. Other types of shocks also disrupt industrial production, causing fluctuations similar to those of oil price shocks. Variance analysis revealed that the primary factor influencing changes in industrial production is its past values, accounting for 41% of the variation. Global price shocks and interest rate changes rank second and third, contributing 39% and 13%, respectively, while overall production explains 4%, with other variables having minimal influence in the long term. The study emphasized that global prices and interest rates significantly affect industrial production, suggesting that the central bank could leverage interest rates, as a monetary policy tool, to maximize industrial sector growth. Mirhosseini et al. (2023) during a study investigated the effect of OPEC oil prices on Iran's industrial production using the quantile regression approach. According to the results of the present research, the effect of OPEC oil price on Iran's industrial production index is positive and significant in all quantiles except the second quantile, which has a negative and significant effect on Iran's industrial production index. Pordel & Esfandiari (2024) investigated the impact of economic policy

[1] In mathematics, the continuous wavelet transform (CWT) is a formal (i.e., non-numerical) tool that provides an overcomplete representation of a signal by letting the translation and scale parameter of the wavelets vary continuously.

uncertainty on oil prices in OPEC member countries. The results showed that the alternative energy index and the interest rate index are stable with a stable interval. Also, the added value index of the industrial sector intermittently affects the real price of oil. Mousavi et al. (2024) investigated the effects of economic policy uncertainty, global geopolitical risk and global uncertainty on oil price fluctuations in Iran. The results of the study showed that the variable of global uncertainty, oil price with one and three periods of interruption affects oil price fluctuations. Also, the long-term estimation results showed that the variables of economic policy uncertainty and global uncertainty affect oil price fluctuations. Masoudi Alavi & Nadiri (2024) investigated the asymmetric effect of oil price fluctuations on investors' sentiments in Tehran Stock Exchange with the NARDL approach. The results showed that the relationship between oil price fluctuations and investors' sentiment index is asymmetrical in the short term and symmetrical in the long term. In the long term, there is a significant relationship, that is, the price of oil in the ups and downs of the market has a different effect in the short term and a similar effect in the long term on investors' feelings, and on the other hand, in the short term and Long-term oil price fluctuations affect investors' sentiments with different intensity. Shawalpour et al. (2024) investigated the asymmetric effect of oil price, exchange rate and their uncertainty on unemployment in oil exporting countries. The results showed that positive oil price shocks have a significant effect on unemployment rate in the short term and Negative changes in oil prices have no effect on the unemployment rate in the short term. While in the long run, the impact of a positive oil shock on unemployment is greater than a negative oil shock. On the other hand, positive changes in the exchange rate (decrease in the value of the national currency against foreign currency) are significant in the short term and have a negative impact on unemployment.

Cheng et al. (2019) highlighted two key reasons why oil price fluctuations are a major concern for private companies. First, oil is a vital input in many production processes, so price changes, known as oil price shocks (first-moment measure), directly affect production costs. Second, oil price uncertainty, which refers to unexpected changes in future oil prices (second-moment measure), influences company expectations about current production and investment decisions. It is crucial to distinguish between first and second-moment variability, as these changes do not always align, and volatility can rise during both price increases and decreases. Punzi (2019) argued that oil price uncertainty can hinder GDP growth because companies postpone investment decisions due to uncertainty about future oil costs, while households delay consumption to save for precautionary reasons. Benavidez & Hira (2019) examine how the uncertainty of international oil prices affected Mexico's economic activity from 1983 to 2017, and found that uncertainty has a negative effect on Mexico's economic activity. Furthermore, they show the presence of asymmetric effects, because the production growth rate increases (decreases) after a negative (positive) oil price shock. Similarly, Maghyereh & Abdoh (2020) suggested that oil price uncertainty leads to reduced investments and lower capacity utilization, which ultimately results in slower output growth. This occurs because companies delay irreversible investments to gather more information about future oil prices, avoiding costly resource reallocations. However, this cautious approach leads to a decrease in overall output. Le et al (2021) investigated the historic oil price fluctuation during the Covid-19 pandemic. The results reveal that increases in Covid-19 pandemic cases, US economic policy uncertainty, and expected stock market volatility contributed to the fall in the WTI crude oil price, whereas the fall in the global stock markets appears to significantly reduce the fall. Furthermore, the Russia–Saudi Arabia oil price war and speculation on oil futures are shown to play a critical part in the collapse of the oil markets. The findings are consistent with our expectations. Although it is reasonable to assume that the solution to this oil crisis is a pick-up in global oil demand, which will occur only when the novel coronavirus is defeated, this study proposes policy recommendations to cope with the current oil price crash. Alao & Payaslioglu (2021), investigated oil price uncertainty and industrial production in oil exporting countries. According to the results of DCC and cDCC parameters, dynamic links are constantly moving between oil prices and industrial production in Brazil and Mexico, and there is a temporary interdependence between oil prices and industrial production in the world. According to the results of symmetric and asymmetric estimation, past news and delayed volatility show a significant effect on the current conditional volatility of the variables. This study also reports that the corrected cDCC-GARCH indeed confirms the DCC-GARCH estimates, further showing that the asymmetric GJR-GARCH model outperforms the symmetric GARCH models. Past news and lagged volatility show a significant effect on current conditional volatility of variables. This study also reports that the corrected cDCC-GARCH indeed confirms the DCC-GARCH estimates and further shows that the asymmetric GJR-GARCH model outperforms the symmetric GARCH models. Abdelsalam (2023), investigated Oil price fluctuations and economic growth in MENA countries. Result showed that changes in oil price and its volatility have an opposite effect for each oil-export and oil-import countries; for the former, changes in oil prices have a positive impact but the volatility a negative effect. While for the latter, changes in oil prices have a negative effect but volatility a positive effect. Further, the impact of oil price changes and their uncertainty are different across different quantiles. Furthermore, there is evidence about the asymmetric effect of the oil price changes on economic growth.

Despite the plethora of research on the interdependence between oil and stock markets, it is evident that the co movement of oil price with respect to industrial production is yet to be studied. The current study therefore attempts to contribute to the existing literature by examining the control or interconnectivity between oil price co movement and industrial production in the select countries. This study aims to bridge this gap by analyzing the interplay between oil price movements and industrial production in selected countries.

3. The Study Model

Multivariate conditional heterogeneous variance method has been used to analyze and estimate the data of this study. These models are less used in Iran. In general, univariate models cannot be used to estimate uncertainty. Also, the important issue in this field is the existence of correlation between its elements, but the single variable model is not able to describe it. In this section, multivariate GARCH models that focus on the correlation between elements are examined.

A general classification of MGARCH models can be presented as follows:

The main difference in the above approaches that have been developed to build MGARCH models is in the specifications that these approaches use for the conditional variance-covariance matrix (Bauwens et al., 2006).

According to the above classification, dynamic conditional correlation (DCC)[1]models are actually nonlinear combinations of univariate GARCH models. This model allows specifying the conditional variance on one side and the conditional correlation matrix on the other side separately. The conditional variance matrix (Ht) is specified in this group of models through a hierarchical process, so that first a GARCH type model is selected for the conditional variance, and then the conditional correlation matrix is modeled based on the conditional variance of the first step. The conditional variance-covariance matrix is defined as follows in the DCC model.

$$H_t = D_t R_t D_t \tag{1}$$

Where:

$$D_t = diag\,(h_{11t}^{1/2} \ldots h_{NNt}^{1/2}) \tag{2}$$

Table 1. Types of MGARCH models

Nonlinear combination of univariate GARCH models	Linear combination of univariate GARCH models	Direct generalization of Balerslow's (1986) univariate GARCH models
CCC (Constant Conditional Correlation Model) DCC (Dynamic Conditional Correlation Model) GDC (General Dynamic Covariance Model) Copula-Garch Models	Generalized Orthogonal Models (OGARCH, GO-GARCH) Latent Factor	VEC BEKK Factor Models Flexible MGARCH Risk metrics Full Factor GARCH Models

Source: *Bauwens et al., 2006*

[1] Dynamic Conditional Correlation (DCC) Model

D_t is a diagonal matrix whose i[th] component on its diagonal corresponds to the conditional standard deviation of the i[th] asset (($h_{iit}^{1/2}$)). It can be defined as any univariate GARCH model. The original version of the DCC model presented by Engel (2002), which is briefly shown as $DCC\,E(1,1)$ is the specification of $GARCH(1,1)$ for each conditional variance in D_t ; In other words:

$$h_{iit} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{ii,t-1} \qquad i = 1, \ldots\ldots, N \tag{3}$$

Finally, R_t is a matrix that includes time-varying conditional correlation in such a way that:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{4}$$

$$Q_t = (1 - \sum_{r=1}^{R} \delta_r - \sum_{s=1}^{S} \gamma_s)\bar{Q} + \sum_{r=1}^{R} \delta_r Q_{t-r} + \sum_{s=1}^{S} \gamma_s (\nu_{t-s} \nu'_{t-s}) \tag{5}$$

In the above model, the unconditional covariance matrix is the vector of standardized residuals (ν_t)in the first stage of estimation, and (Q_t^*) is the diagonal matrix composed of the square root of the diagonal elements. Engle and Sheppard (2001) showed that δ and γ must be non-negative to be positive definite (Q_t). In this case, R_t will also be positive (Engle & Sheppard, 2001).

The logarithm of the exponential function to estimate the parameters of the DCC model can be specified as follows:

$$L(\theta) = -\frac{TN}{2}\log 2\pi - \frac{1}{2}\sum_{t=1}^{T}(\log|H_t| - \varepsilon'_t H_t^{-1} \varepsilon_t)$$

$$= -\frac{TN}{2}\log 2\pi - \frac{1}{2}\sum_{t=1}^{T}(\log|D_t R_t D_t| - \varepsilon'_t D_t^{-1} R_t^{-1} D_t^{-1} \varepsilon_t)$$

$$= -\frac{TN}{2}\log 2\pi - \frac{1}{2}\sum_{t=1}^{T}(2\log|D_t| + \log|R_t| - \nu'_t R_t^{-1} \nu_t) \tag{6}$$

The modeling of the current research consists of two parts: First, it has been tried to test the existence of contagion phenomenon in oil price and industrial production index of Iran, Saudi Arabia, UAE and OECD countries by using correlation coefficient analysis and common t test. For this purpose, the following linear regression model can be considered:

$$y_{it} = \beta y_{jt} + \varepsilon_{it} \tag{7}$$

If there are changes in the relationship between the yield series y_{it} and y_{jt} (which is shown as a significant change in β), it will be evidence of the existence of contagion. This simple test will be complicated when the change in volatility of the disturbance component while moving from the non-critical period to the critical period is considered. Such behavior is contrary to the assumption of homogeneity of variance and is part of disturbance. Forbes and Rigoben (2000) proposed a test of statistical change in the correlation coefficient, ρ_i ، between two critical and non-critical periods in order to avoid this problem. Considering that the variance of the data is expected to increase upon entering the critical period compared to the non-critical period, Forbes and Rigoben presented the following adjustment for the correlation coefficient:

$$\rho_i^* = \frac{\rho_i}{\sqrt{1+\delta\left[1-(\rho_i)^2\right]}} \tag{8}$$

Where, $\delta = \frac{\sigma_j^h}{\sigma_j^l} - 1$ and it represents a relative increase in the variance of asset yield between the non-crisis period (stability) and the crisis period. Finally, in order to test the significance of the increase in the adjusted correlation coefficient, the following hypotheses can be considered:

$$\begin{cases} H_0: \rho_1^* \le \rho_2^* \\ H_1: \rho_1^* \succ \rho_2^* \end{cases} \tag{9}$$

$$t = (\rho_1^* - \rho_2^*)\sqrt{\frac{n_1+n_2-4}{1-(\rho_1^*-\rho_2^*)^2}} \qquad df = (n_1 + n_2 - 4) \tag{10}$$

ρ_1^* :Correlation coefficient in the crisis period

ρ_2^* : Correlation coefficient in the non-critical period

The test of the above hypothesis can be done using the t-Student test, whose test statistic is defined as follows:

Accepting the competitor hypothesis will indicate the presence of contagion in the market.

Accepting the competitor hypothesis will indicate the presence of contagion in the market.

The multivariate GARCH model $DCC(1,1)$ has been used as a basic model to examine the time-varying conditional correlation in the next step. At this stage, considering that in the test of the existence of financial contagion through time-varying conditional correlation, contagion is defined as a significant structural failure in the dynamic correlation series in crisis periods, the dynamic time-varying conditional correlation in order to Showing the turbulent period is adjusted for this purpose; Therefore, the standard form of the model introduced by Engel (2002) and its adjusted form will be as follows:

Model (1):

$$DCC(1,1)$$
$$r_{jt} = \mu_j + \rho r_{j,t-1} + \varepsilon_{jt}$$
$$h_{jt} = k_j + \alpha_j \varepsilon^2_{j,t-1} + \beta_j h_{j,t-1}$$
$$Q_t = (1-\delta-\gamma)\bar{Q} + \delta Q_{t-1} + \gamma(\nu_{t-1}\nu'_{t-1}) \quad (11)$$

Model (2): Adjusted

$$r_{jt} = \mu_j + \rho r_{j,t-1} + \varepsilon_{jt} \quad (12)$$
$$h_{jt} = k_j + \alpha_j \varepsilon^2_{j,t-1} + \beta_j h_{j,t-1}$$
$$Q_t = (1-\delta-\breve{\delta}D-\gamma)\bar{Q} + (\delta+\breve{\delta})Q_{t-1} + \gamma(\nu_{t-1}\nu'_{t-1})$$

In the adjusted model, D represents an imaginary variable that has considered a value of 1 for the critical period, and will be zero otherwise. $\breve{\delta}$ is the coefficient of an imaginary variable, and it includes it in case of a change in the conditional correlation. The necessary restrictions for the positive definiteness of the covariance matrix in the adjusted model will be as $\delta \geq 0, \breve{\delta} \geq 0$ and $\delta + \breve{\delta} + \gamma \prec 1$. Using model (2) as an unrestricted model, the likelihood ratio (LR)[1] test for the presence of contagion is performed against model (1) with the null hypothesis $H_0 = \breve{\delta} = 0$. The mentioned test statistic will have a distribution χ^2 with one degree of freedom.

4. Empirical Results

This research has used the monthly data of oil price (OP), industrial production of Iran, Saudi Arabia, UAE and 35 selected countries from OECD countries in the period from 2000 to 2021 on a monthly basis[2]. Oil prices are measured in US dollars from the US Energy Information Administration (2020) from FRED, which is the Federal Reserve Bank of St. Louis. Also, this study uses IPI-OECD to represent world industrial activity or world gross domestic product (GDP) from the OECD website. Since multivariate GARCH models need to be stable over time, the growth rate is calculated using the following continuous compound growth rate formula for each of the series:

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[1] The Likelihood Ratio (LR) is the likelihood that a given test result would be expected in a patient with the target disorder compared to the likelihood that that same result would be expected in a patient without the target disorder.

[2] The Organization for Economic Co-operation and Development (OECD) is an international organization that works to build better policies for better lives. We draw on more than 60 years of experience and insights to shape policies that foster prosperity and opportunity, underpinned by equality and well-being. The OECD's 38 Member countries span the world, from North America and South America to Europe and Asia-Pacific.

$$growth = \log(\varepsilon_t / \varepsilon_{t-1}) \quad (13)$$

ε_t shows the series. The variables are: oil, Iran, Saudi Arabia, the UAE and OECD countries, BetterTib indicates the return of oil prices, the return of the industrial production index of Iran, Saudi Arabia, the UAE and OECD countries.

Table (2) shows the summary statistics of the data. As it was said, the generalized Dickey–Fuller test has been used in order to check the reliability of the studied time series, which the results of the generalized Dickey–Fuller (ADF) test in table (3) show that at the level The price of oil, the industrial production index of Iran, Saudi Arabia, UAE and OECD countries are stable, and the result of the generalized Dickey–Fuller test indicates that the variables are stable at the level.

Table 2. Summary statistics of oil price data and industrial production index of Iran, Saudi Arabia, UAE and OECD countries

	OP	Iran	Saudi	Emirates	OECD
Mean	0.0019	0.0005	0.0019	0.0017	0.0010
Median	0.0009	0.0016	0.0015	0.0021	0.0011
Maximum	0.0927	0.01039	0.0114	0.0104	0.0044
Minimum	0-1441	0-0182	-0.0096	-0.0105	-0.0031
std.Dev.	0.0346	0.0069	0.0048	0.0047	0.0018
Skewness	0-8520	-0.7723	-0.0929	0.4717	-0.1018
kurtosis	5.5418	2.6701	2.4137	2.6177	2.2865
Jarque-bera	103.010	427.441	4.1604	11.4006	6.0563
Probability*	0.00	0.00	0.12	0.00	0.04
observations	264	264	264	264	264

Probability*: *shows the probability related to the assumption of normality of the series.*
Source: *research findings*

Table3. The results of the generalized Dickey-Fuller test

Degree of accumulation	ADF statistics		Variable
	Data difference	Data level	
I(0)	-	***-12.203	OP
I(0)	-	***-3.273	Iran
I(0)	-	***-5.032	Saudi
I(0)		***-4.539	Emirates
I(0)	-	***-5.968	OECD

, **, * are significant respectively at the level of 90, 95, 99%*
Source*: research findings*

Table (2) shows the mean, median, maximum, minimum, standard deviation, skewness, kurtosis and Jarque-bera statistic. According to the descriptive table, the series has more elongation than the normal distribution, and the result of the Jarque-bera statistic also indicates the fact that the hypothesis of normality of returns is rejected. Not all return series are normally distributed. A positive skewness statistic means that the series has a longer right sequence than the left sequence. The high elongation of the distribution of returns shows that the market gives more probability to the extreme values compared to when the distribution of returns is normal. Chart (1) shows the level charts for oil prices, the production index of Iran, Saudi Arabia, UAE and OECD countries.

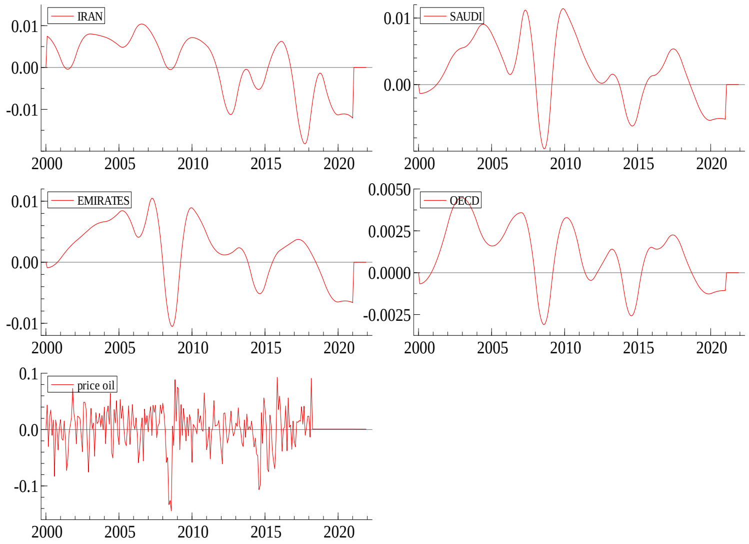

Chart 1. Area charts for oil prices, industrial index of Iran, Saudi Arabia, UAE and OECD countries

***Source**: research findings*

4.1 Model estimation using CDCC-GARCH method

In this part, the model is analyzed using the CDCC-GARCH method. A number of equations have been estimated to specify and estimate the model using autocorrelation functions and partial autocorrelation functions and based on the Akaike information criterion (AIC)[1] and Schwarz's Bayesian criterion (SBC) and according to other criteria, including the logarithm of the likelihood of the AR (1)-GARCH model was selected.

Also, the Ljung-Box Hosking, Li and McLeod test on the standardized residuals and their squares, which are used in the multivariate GARCH model, confirmed the appropriateness of the mean and variance model due to the absence of serial correlation and the absence of the heterogeneity variance effect in the residuals. Now, the return logarithm of different assets is estimated using the maximum likelihood method using the time-varying covariance matrix estimated by the CDCC (1,1) model. Since the probability value corresponding to the Hosking, Li, and McLeod test on the standardized residuals is less than 0.05, there is no autocorrelation in the residuals, and the mean model is correctly specified.

[1] The Akaike information criterion (AIC) is an estimator of prediction error and thereby relative quality of statistical models for a given set of data.

Because the probability value related to the Hosking, Li and McLeod test on the squared standardized residuals is smaller than 0.05, there is no heterogeneity variance in the residuals and the variance model is appropriate.

The industrial production index of Iran, Saudi Arabia, the UAE and OECD countries, the CDCC-GARCH model is estimated by the maximum likelihood method to determine the dynamic correlation between oil prices. According to the results, parameters α and β are significantly different from zero, and the conditions $\alpha \geq 0$ و $\beta \geq 0$ ،, $\alpha + \beta \prec 1$ are satisfied, show that the time-varying conditional correlation model is more suitable than the fixed conditional correlation model. Chart 2 shows the conditional correlation of variable with time between different variables.

Table 4. Autocorrelation and variance heterogeneity tests in the CDCC-GARCH model

Statistics	Q	P-values	Q^2	P-values
Hosking(5)	1376.94	0.000	343.142	0.000
Hosking(10)	2007.50	0.000	444.761	0.000
Hosking(20)	3109.24	0.000	685.379	0.000
Li-McLeod(5)	1368.84	0.000	341.806	0.000
Li-McLeod(10)	1981.21	0.000	444.271	0.000
Li-McLeod(20)	3034.78	0.000	685.167	0.000

Source: *research findings*

According to chart 2, the correlation between oil price and the industrial index of Iran, Saudi Arabia, the UAE and OECD countries is positive in most of the studied period. However, this positive correlation has been increasing in most of the graphs, and has reached the value of 1 in some years. While, the correlation charts between oil price and industrial production index of Saudi Arabia, UAE, Iran and OECD countries have decreased to zero or less. The reason for this positive correlation of oil price with the industrial production index of Saudi Arabia, UAE, Iran and OECD countries is that during the global financial crisis, with the decrease in demand for oil, the price of oil also decreased and this caused the decrease in the gross domestic product of the mentioned countries. As a result, investors prefer to invest in other things, and this, in turn, causes an excessive decrease in the price of oil.

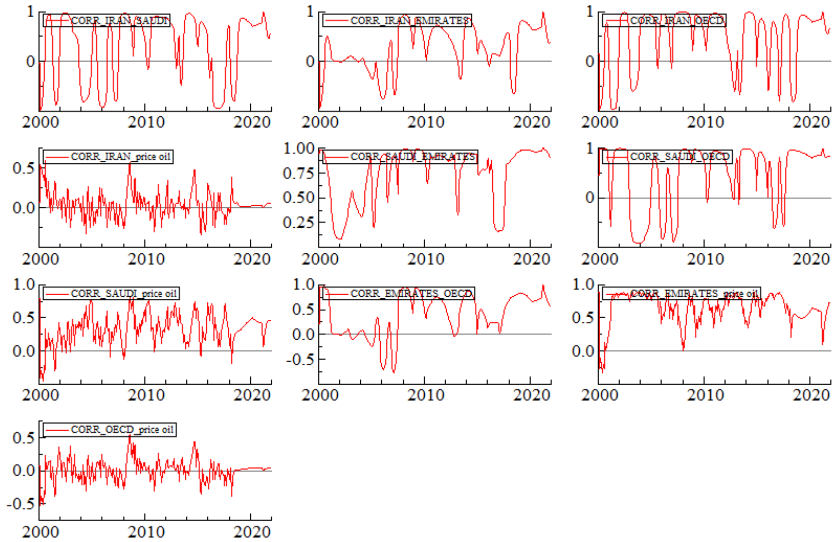

Chart 2. Dynamic conditional correlation in the CDCC-GARCH model

***Source**: research findings*

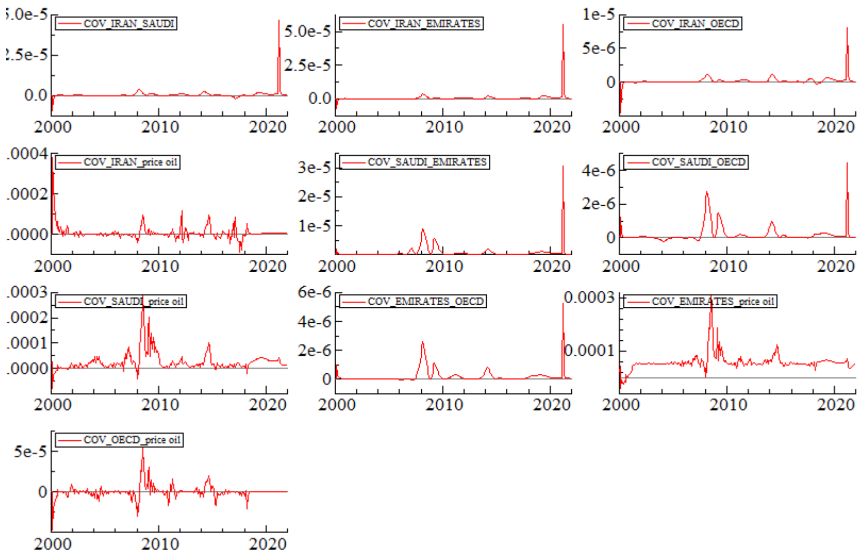

Chart 3. Dynamic conditional covariance in CDCC-GARCH model

***Source**: research findings*

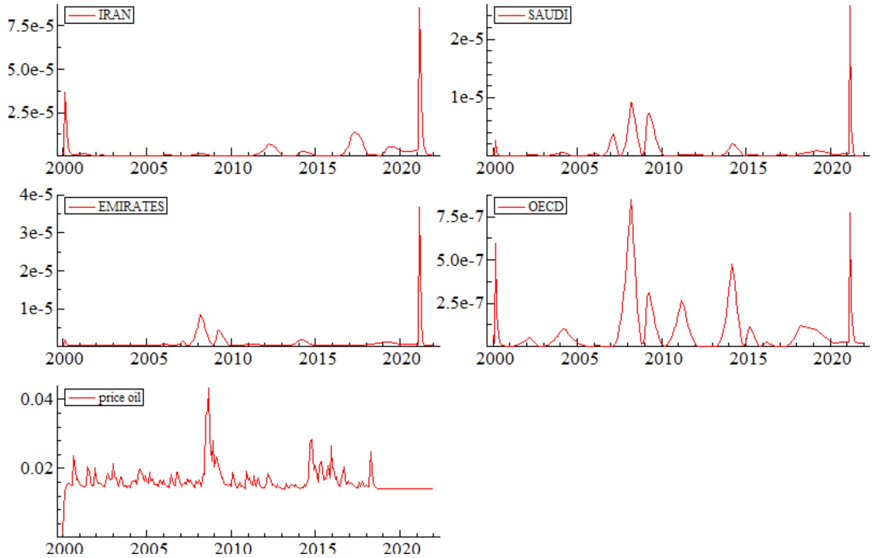

Chart 4. Dynamic conditional variance in CDCC-GARCH model

***Source**: research findings*

Chart 5. The standard residual of the variables in the CDCC-GARCH model

***Source**: research findings*

Table 5. CDCC-GARCH model estimation results

variable correlation	Coefficient
$\rho_{Saudi\ ,Iran}$	-0.0450

$\rho_{OECD,Iran}$	-0.0144
$\rho_{OP,Iran}$	0.1419
$\rho_{Emirates,Iran}$	0.0742
$\rho_{OECD,\text{Saudi}}$	0.9526
$\rho_{OP,\text{Saudi}}$	0.4609
$\rho_{Emirates,\text{Saudi}}$	0.7934
$\rho_{OP,OECD}$	0.2170
$\rho_{Emirates,OECD}$	0.8892
$\rho_{Emirates,OP}$	0.0828
alpha	0.63
beta	0.36
Log Likelihood	7990.713

Source: *research findings*

4.2 Model estimation using GJR-GARCH model

The model has been examined with GJR-GARCH method after examining the model using two DCC-GARCH and CDCC-GARCH methods. Partial autocorrelation functions and Akaike and Schwartz-Bayesian criteria as well as the logarithm of the GJR (1,1) model were chosen to specify and estimate the model. Also, Ljung-Box Hosking, Li and McLeod tests on the standardized residuals and their squares, which are used in the multivariate Garch model, due to the absence of serial correlation and the absence of the effect of heterogeneity variance in the residuals, the appropriateness of the average model and confirmed the variance. Now, using the time-varying covariance matrix estimated by the GJR (1,1) model, the logarithm of the yield of different assets is estimated using the maximum likelihood method. Since the probability value related to the Hosking, Li and McLeod test on the standardized residuals is less than 0.05, there is no autocorrelation in the residuals and the mean model is correctly specified. And because the probability value related to the Hosking, Li and McLeod test on the squared standardized residuals is smaller than 0.05, there is no heterogeneity variance in the residuals and the variance model is suitable.

The GJR-GARCH model is estimated by the maximum likelihood estimation (MLE)[1] to determine the dynamic correlation between oil prices, the industrial production index of Iran, Saudi Arabia, UAE and OECD countries. According to the results, the parameters □ and □ are significantly different from zero, and the conditions ($\alpha \geq 0$, $\beta \geq 0$), and $\alpha + \beta \prec 1$ are satisfied, show that the time-varying conditional correlation model is more suitable than the fixed conditional

[1] In statistics, maximum likelihood estimation (MLE) is a method of estimating the parameters of an assumed probability distribution, given some observed data. This is achieved by maximizing a likelihood function so that, under the assumed statistical model, the observed data is most probable.

correlation model. Chart (4-6) shows the time-varying conditional correlation between different variables

Table 6. Autocorrelation and variance heterogeneity tests in the GJR-GARCH model

Statistics	Q	P-values	Q^2	P-values
Hosking(5)	1287.34	0.000	338.996	0.000
Hosking(10)	1579.30	0.000	364.338	0.000
Li-McLeod(5)	1278.30	0.000	338.574	0.000
Li-McLeod(10)	1565.27	0.000	366.952	0.000

Source: *research findings*

According to chart 6, unlike the previous two models, there is a negative correlation between the oil price and the industrial index of Iran, Saudi Arabia, UAE and OECD countries in most of the studied period, and their fluctuations range from -0.5 to 0.5. UAE has experienced more negative correlation than other countries. Meanwhile, Saudi Arabia and OECD countries have the most negative correlation. The relationship between oil price and industrial index in Iran is fluctuating like the previous two models, and shows a positive correlation from 2018 onwards. Saudi Arabia, UAE and OECD countries, unlike Iran, show a negative correlation between oil price and industrialization index in the mentioned period, which is due to the different economic structure of these countries. In other words, Iran has shown a different behavior compared to other countries due to its greater dependence on oil and its products.

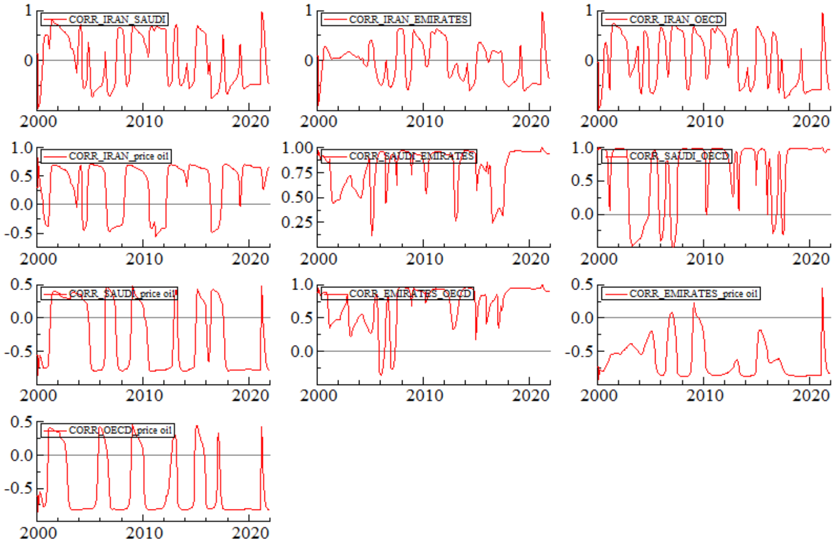

Chart 6. Dynamic conditional correlation in GJR-GARCH model

Source: *research findings*

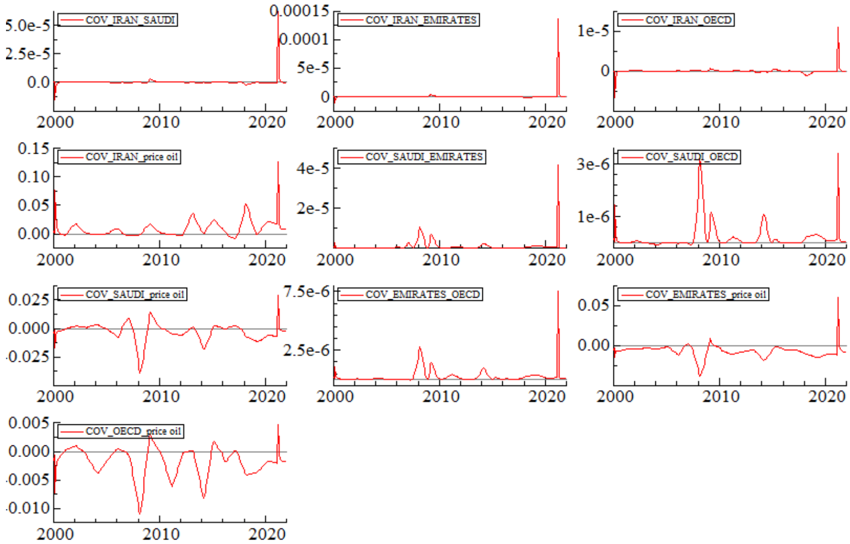

Chart 7. Dynamic conditional covariance in the GJR-GARCH model

Source: *research findings*

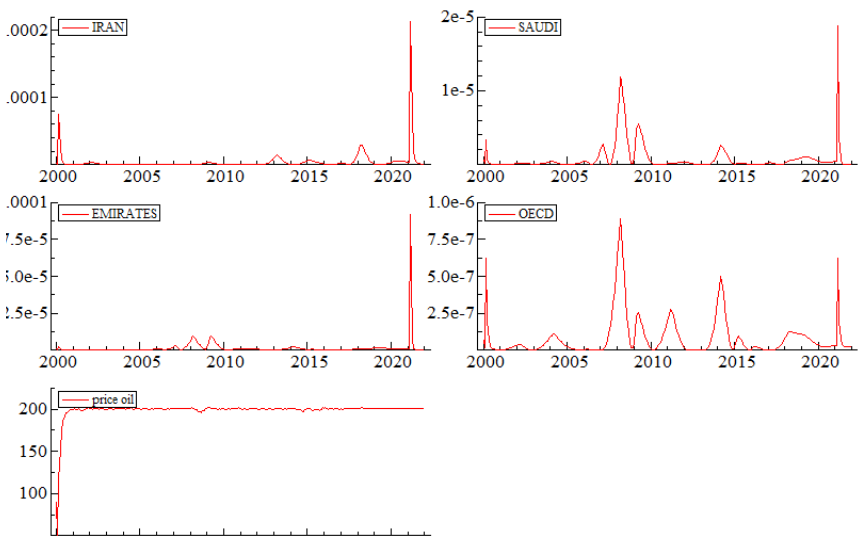

Chart 8. Dynamic conditional variance in the GJR-GARCH model

Source: *research findings*

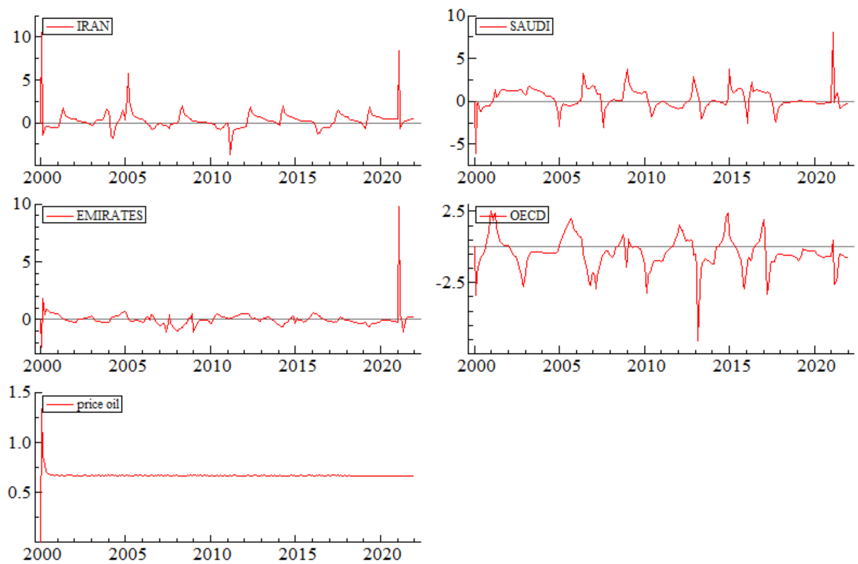

Chart 9. The standard residual of the variables in the GJR-GARCH model
Source: *research findings*

Table 7. GJR-GARCH model estimation results

Variable correlation	Coefficient
$\rho_{Saudi, Iran}$	0.1193
$\rho_{OECD, Iran}$	0.0896
$\rho_{OP, Iran}$	-0.0329
$\rho_{Emirates, Iran}$	0.3032
$\rho_{OECD, \text{Saudi}}$	0.9264
$\rho_{OP, \text{Saudi}}$	0.9648
$\rho_{Emirates, \text{Saudi}}$	-0.5584
$\rho_{OP, OECD}$	0.8932
$\rho_{Emirates, OECD}$	-0.7418
$\rho_{Emirates, OP}$	-0.6144
alpha	0.44
beta	0.34
Log Likelihood	6537.029

Source: *research findings*

According to the above models, it can be concluded that there is a significant relationship in all three models between the oil price and the industrialization index in the studied countries, but the difference is that there is a negative relationship between oil price fluctuations and the industrialization index. It has been shown that in the GJR-GARCH model, except for Iran, where a positive relationship between fluctuations is observed in the last years of the period, the rest of the studied countries have shown negative relationships, which can be attributed to the economic structure of the countries.

5. Concluding Remarks

This study has been conducted in order to investigate the symmetric and asymmetric behavior of fluctuations in Iran, Saudi Arabia, UAE and OECD countries based on the monthly price of oil and the growth of the IP index using CDCC-GARC models from January 2000 to December 2021. According to the results, oil price fluctuations have a significant effect on the industrial production of the studied countries. The following studies confirm this: Arsalani (2001), Tamizi (2002), Mehrara & Niki Eskoui (2016), Fallahi and Peyghambari (2012), Abrishami et al. (2008), Samadi et al. (2009), Eltejaei & Afzali (2013), Rajabi & Karimi (2016), Tak Roosta et al. (2018), Khoshkalam Khosrowshahi (2018), Hosseininia & Fatahi (2019), Lotfalipour et al. (2020), Mirhosseini et al. (2023), Reyes & Ragwindin (2005), Farzangan & Marquad (2009), Kumar (2009), Mehrara & Sarem (2009), Pappetro (2009), Ahmed et al. (2012), Rodriguez and Sanchez (2019), Bayar and Kilic (2014), Wang and Zhang (2014), Liu et al. (2014), Jiraniakol (2016), Dudin et al. (2017), Van Eyden et al. (2019), Sarver et al. (2021), Alao and Payasligulu (2021); therefore, the research hypotheses are confirmed.

There are some important policy implications of the findings. In the current study, the policymakers of oil-rich countries should examine modalities to absorb a strong oil price shock and prevent the occurrence of oil price uncertainty in the future. The results show that the interdependence of oil prices and industrial production in Saudi Arabia, UAE, OECD countries will continue for a long time. In general, the dependence of the studied countries on oil exports and thus on oil revenues cannot be rejected. Correlation coefficients indicate the significant correlation between GDP and oil revenues. The increase in global oil prices causes an increase in the gross domestic product (GDP), which is caused by an increase in all components of GDP.

It is recommended to reduce the share of oil in the economy by developing non-oil sectors such as industry, agriculture, and services. Additionally, creating favorable conditions to encourage investors to invest in high value-added and export-oriented industries can help generate sustainable income flows, which would be effective in diversifying the economy and reducing dependency on oil. Establishing oil revenue stabilization funds to manage income fluctuations and finance key industrial projects during periods of declining oil prices, as well as adjusting interest rates and monetary policies to prevent severe fluctuations in industrial production, are other useful suggestions in this regard. Developing alternative and sustainable energy sources, especially for a country like Iran with many sunny days, can contribute to reducing dependency on oil and its price volatility. Finally, prioritizing strategic industries that are less reliant on oil prices can significantly aid in formulating sustainable industrial and energy policies. Therefore, policymakers in oil-rich countries should draw strategies for oil price fluctuations in order to prevent the occurrence of oil price uncertainties in the future. Furthermore, policymakers need to establish sustainable structural adjustment programs with long-term policy reviews to mitigate the effects of future oil price fluctuations. As uncertainty in the future of oil prices increases, production must be adjusted sharply until this uncertainty and unpredictability is finally resolved.

Author Contributions

Conceptualization, all authors; methodology all authors; formal analysis, all authors; resources, all authors; writing—original draft preparation, all authors; writing—review and editing, all authors; supervision, Mousavi, S.N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data used in the study were taken from https://fred.stlouisfed.org/ & https://www.oecd.org

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