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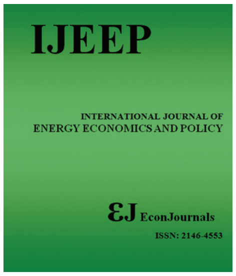
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The asymmetric Impact of COVID-19 Pandemic on the Crude Oil-stock Markets Nexus in KSA: Evidence from a NARDL Model

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ABSTRACT

This paper estimates the asymmetric relationship between the crude oil market, stock market and COVID-19 pandemic in the case of KSA during the period of March 15, 2020–February 03, 2021. Nonlinear and long-run asymmetric cointegration were utilized for comprehensive research on this topic. Our findings are as follows: positive and negative shocks to the COVID-19 pandemic reduce stock market. Moreover, positive shock to crude oil market increases stock market, but negative shock has a negative and insignificant effect. Based on the results, this study concludes with suitable policy prescription.

Keywords: COVID-19 Pandemic, Crude Oil, Stock Markets, NARDL Model, The Asymmetric
JEL Classifications: C32, G14, G10, G11.

1. INTRODUCTION

World Health Organisation (WHO) declared, on March 11 2020, the COVID-19 as a global pandemic. Based on WHO's world meters website as of October 21 2021, there are 242,916,887 confirmed cases, 220,169,977 recoveries and 4,939,857 deaths across the world. Concerning the Kingdom of Saudi Arabia, there are 548,065 confirmed cases, 537,095 recoveries and 8,770 deaths (Saudi Ministry of Health-Sehhty). The appearance of this pandemic has caused an important effect on the global trade. In this regard, along with a big knockout of domestic trading and international business, COVID-19 has induced significant negative influences on the performance of different stock markets worldwide (Anh and Gan, 2021; Al-Awadhi et al., 2020; Alfaro et al., 2020; Zhang et al., 2020). Several studies have investigated the impact of COVID-19 and its lockdown on stock markets (e.g., Sharif et al., 2020; Kodres, 2020; Al-Awadhi et al., 2020; Alfaro et al., 2020; Eleftheriou and Patsoulis, 2020; He et al., 2020; Zhang et al., 2020). This idea is proved by Alfaro et al. (2020), who identify a negative impact of COVID-19 on US stock returns. In the same line of idea, Zhang et al. (2020) underline the same relationship between COVID-19 and the stock markets in neither the ten most affected countries by this novel pandemic in March 2020 nor in the stock markets of Japan, Korea and Singapore. In addition, other studies, presented by He et al. (2020) and Liu et al. (2020) as well as Anh and Gan (2021), stipulate that COVID-19 pandemic has a negative impact on multiple countries' stock returns.

In this context, the issue of the impact of the pandemic on macro-economic performance has attracted a lot of attention. Numerous studies have attempted to explore and explain the interaction between the pandemic and macro-economic variables (Leoni, 2013), governments, public and financial markets (Chen et al., 2018). Results from earlier studies have demonstrated a strong association between pandemic and macroeconomic performance, owing to the pandemic's enormous economic cost (Bloom et al., 2018; Liu et al., 2020). Related to the stock market performance and to the oil-importing economies, oil prices represent the major predictor in this domain. It means, according to (Narayan et al., 2014), that a decrease in the oil prices leads to a lower production cost play but an increase in the economic growth.

However, the recent decline in oil prices due to the COVID-19 pandemic along with plummeting stock markets globally included in oil-importing economies, raises the question of whether the well-established negative relation between oil and stock prices holds. Also, according to Vidya and Prabheesh (2020), due to the lockdowns, the overall demand was reduced. In this way, the crude oil price fell as a result of the sharp reduction in consumption from US$61 on January 2 2020 to US$12 on April 28 2020. So, a positive relationship was distinguished between crude oil prices and stock prices. By contrast, a negative association between crude oil prices and stock prices was established. Hence, ignoring the relationship between the crude oil market and the stock market and investigating the effect of the COVID-19 may contribute to model misspecification problems and lead to inaccurate results and conclusions. To this end, we attempt to investigate the nexus among these three variables in a unified framework (Liu et al., 2020). It is highlighted, by Mensi et al. (2020), that the crude oil behaved inefficiently during the COVID-19 pandemic, indicating that the oil market is susceptible to the pandemic.

In addition, the increase in COVID-19 cases and deaths impacted the oil and financial markets in the US, Europe, and Asia (Shehzad et al., 2020; Shehzad et al., 2021). The investigation by Salisu et al., 2020 used the panel vector autoregressive model (pVAR) to determine the behavior of the oil and stock markets during COVID-19. The study found that both the oil market and stock markets volatility have a significant impact on oil returns (Salisu et al., 2020). In other way, based in the study prepared by Georgieva (2020), the COVID-19 pandemic has brought the world closer to the most dangerous economic crises. In this context, the fall in oil prices due to the global lockdowns related to COVID-19 requires an investigation of oil stock dynamics from the perspective of net oil-importing countries. Existing research on the COVID-19 pandemic pertains to the study of the oil markets and their impact on various economic factors (Apergis and Apergis, 2020; Fu and Shen, 2020; Gil-Alana and Monge, 2020; Liu et al., 2020; Narayan, 2020; Qin et al., 2020). Therefore, it is indispensable to find out the effect of COVID-19 on the stock markets. Most studies to date have used the SandP 500, Nasdaq Composite, CAC 40, Shanghai composite, or Nikkei 225 indices (Just and Echausi, 2020; Rudden, 2020). However, the extent to which the COVID-19 pandemic and crude oil are impacting equity markets remains unclear. Thus, determining the impact of the COVID-19 pandemic is not only significant for formulating the appropriate investment strategy for investors in advance, but also crucial for governments to deal with the possible fluctuation in crude oil market.

Therefore, the primary aim of this paper is to explore the interaction among the number of confirmed cases of the COVID-19 pandemic, the crude oil market and stock market TADAWEL in Saudi Arabia by utilizing the dataset of KSA COVID-19 pandemic (Liu et al., 2020). Our main contribution to this literature is to explore the impact of the number of confirmed cases of COVID-19 in Saudi Arabia and crude oil prices on the stock market prices in Saudi Arabia during the study period (the period of complete Saudi economy shutdown). In this regard, our approach to examine the relationship between oil prices, COVID-19 and the stock market nexus is as follows. First, we select a country, the Kingdom of Saudi Arabia, and draw a sample of daily observations for the period from March 1, 2020 to February 2, 2021. Second, we implement the NARDL model to evaluate the strength and direction of the relationship between the three variables.

The rest of the paper is distributed as per the following: Section 2 presents the data and methodology. Section 3 analyzes the results and discussion. The last section concludes and suggests some policy implications.

2. DATA AND METHODOLOGY

Our applied studies are based on statistics published by (www.investing.com, (www.coronavirus-statistiques.com). The analysis from the applied side is based on a daily data series during the period form March 1, 2020 to February 2, 2021. A NARDL model will be estimated to discover the non-linear relationship between COVID-19 pandemic and the crude oil prices on stock prices index in the KSA. In this paper, we will try to study the effect of positive and negative changes in COVID-19 pandemic and the crude oil prices on stock prices index in KSA during the period from March 1, 2020 to February 2, 2021. A NARDL model is used in this case. Therefore, before applying it, it is useful to define this model as follows:

Shin et al., (2014) presented the NARDL model. It follows the ARDL model (the approach that popularized through works of [Pesaran and Yongcheol, 1998; Pesaran et al., 2001]). It follows the ARDL model in its steps by specifying the model and then studying the bound test.

We remind that this model itself is an expansion (development) of the long-term asymmetric regression model of the inverse relationship between stock prices index, crude oil price and COVID-19 pandemic. Its formula can be illustrated as follows:

$$TAD_t =^{+} INF_t^{+} +^{-} INF_t^{-} + \beta^{+} WTI_t^{+} + \beta^{-} WTI_t^{-} + u_t \qquad (1)$$

Where: TAD_t, INF_t, WTI_t, represent: stock prices index, COVID-19 pan INF_t^{-} demic (which represents the daily number of infected people in Saudi Arabia), and crude oil price respectively.

Also, INF_t and WTI_t are decomposed as:

$$INF_t = INF_0 + INF_t^{+} + INF_t^{-}$$

$$WTI_t = WTI_0 + WTI_t^{+} + WTI_t^{-}$$

INF_t^{+} and WTI_t^{+}: are partial sum processes of positive changes in INF_t and WTI_t respectively.

INF_t^{-} and WTI_t^{-}: are partial sum processes of negative changes in INF_t and WTI_t respectively.

Whereas, INF_t^+, and WTI_t^+, WTI_t^- are calculated as follows:

$$INF_t^+ = \sum_{i=1}^{t} \Delta INF_i^+ = \sum_{i=1}^{t} \max(\Delta INF_i, 0) \text{ and}$$

$$INF_t^- = \sum_{i=1}^{t} \Delta INF_i^- = \sum_{i=1}^{t} \min(\Delta INF_i, 0)$$

$$WTI_t^+ = \sum_{j=1}^{t} \Delta WTI_j^+ = \sum_{j=1}^{t} \max(\Delta WTI_j, 0) \text{ and}$$

$$WTI_t^- = \sum_{j=1}^{t} \Delta WTI_j^- = \sum_{j=1}^{t} \min(\Delta WTI_j, 0)$$

This approach for asymmetry relationship that depends on partial sum decompositions was used in (Schorderet, 2001) to study the nonlinear relationship between INF, WTI and TAD. After that, this approach was generalized by (SChorderet, 2003) and defined the stationary linear combination of the partial sum components as follows:

$$\begin{aligned} Z_t = {} & \beta_0^+ TAD_t^+ + \beta_0^- TAD_t^- + \beta_1^+ INF_t^+ \\ & + \beta_1^- INF_t^- + \beta_2^+ WTI_t^+ + \beta_2^- WTI_t^- \end{aligned} \tag{2}$$

Here, we say that there is an asymmetric relationship between INF, WTI and TAD or we can say that these two variables are "asymmetrically cointegrated," if and only if Z_t is stationary.

We can illustrate the application of the NARDL model by applying the following steps:

First Step: Extending the aforementioned long-term asymmetric regression model (last part) to become in form of NARDL (p, q, k) as follows:

$$\begin{aligned} TAD_t = {} & \sum_{j=1}^{p} \phi_j TAD_{t-j} + \sum_{j=0}^{q} (\theta_j^+ INF_{t-j}^+ + \theta_j^- INF_{t-j}^-) \\ & + \sum_{j=0}^{k} (\varphi_j^+ WTI_{t-j}^+ + \varphi_j^- WTI_{t-j}^-) + \varepsilon_t \end{aligned} \tag{3}$$

ϕ_j: The Autoregressive Parameter; (θ_j^+, θ_j^-) and (φ_j^+, φ_j^-): are the Asymmetric Parameters of distributed lag; ε_t: Error term. (INF_t^+, INF_t^-) and (WTI_t^+, WTI_t^-) were calculated as we saw previously.

Second Step: Estimate the error correction model (NARDL ECM) as follows:

$$\begin{aligned} & \Delta TAD_t \; \rho TAD_{t-1} + \theta^+ INF_{t-1}^+ + \theta^- INF_{t-1}^- + \varphi^+ WTI_{t-1}^+ + \varphi^- WTI_{t-1}^- \\ & + \sum_{j=1}^{p-1} \gamma_j \Delta TAD_{t-j} + \sum_{j=0}^{q-1} (\sigma_j^+ \Delta INF_{t-j}^+ + \sigma_j^- \Delta INF_{t-j}^-) \\ & + \sum_{j=0}^{k-1} (\lambda_j^+ \Delta WTI_{t-j}^+ + \lambda_j^- \Delta WTI_{t-j}^-) + \varepsilon_t \end{aligned} \tag{4}$$

Where: ρ, θ⁺, θ⁻, φ^+, φ^-: are long-run parameters; σ_j^+, σ_j^-, λ_j^+, λ_j^-: are short-run parameters.

It can also be written as follows:

$$\begin{aligned} & \Delta TAD_t \; \rho \xi_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta TAD_{t-j} \\ & + \sum_{j=0}^{q-1} (\sigma_j^+ \Delta INF_{t-j}^+ + \sigma_j^- \Delta INF_{t-j}^-) \\ & + \sum_{j=0}^{k-1} (\lambda_j^+ \Delta WTI_{t-j}^+ + \lambda_j^- \Delta WTI_{t-j}^-) + \varepsilon_t \end{aligned} \tag{5}$$

Where: $\rho = \sum_{j=1}^{p} \phi_{j-1}$; $\gamma_j = -\sum_{i=j+1}^{p} \phi_i \rightarrow j = 1, 2, \ldots, p-1$;

$\theta^+ = \sum_{j=0}^{q} \theta_j^+$; $\theta^- = \sum_{j=0}^{q} \theta_j^-$;

$\varphi^+ = \sum_{j=0}^{q} \varphi_j^+$; $\varphi^- = \sum_{j=0}^{q} \varphi_j^-$

$\sigma_0^+ = \theta_0^+$; $\sigma_j^+ = -\sum_{i=j+1}^{q} \theta_j^+ \rightarrow j = 1, 2, \ldots, q-1$;

$\sigma_0^- = \theta_0^-$; $\sigma_j^- = -\sum_{i=j+1}^{q} \theta_j^- \rightarrow j = 1, 2, \ldots, q-1$;

$\lambda_0^+ = \varphi_0^+$; $\lambda_j^+ = -\sum_{i=j+1}^{k} \varphi_j^+ \rightarrow j = 1, 2, \ldots, k-1$;

$\lambda_0^- = \varphi_0^-$; $\lambda_j^- = -\sum_{i=j+1}^{k} \varphi_j^- \rightarrow j = 1, 2, \ldots, k-1$;

$$\begin{aligned} \xi_{t-1} = {} & TAD_{t-1} - \frac{-\theta^+}{\rho} INF_{t-1}^+ - \frac{-\theta^-}{\rho} INF_{t-1}^- \\ & - \frac{-\varphi^+}{\rho} WTI_{t-1}^+ - \frac{-\varphi^-}{\rho} WTI_{t-1}^- \end{aligned}$$

$$\xi_{t-1} = TAD_{t-1} - \beta_1^+ INF_{t-1}^+ - \beta_1^- INF_{t-1}^- - \beta_2^+ WTI_{t-1}^+ + \beta_2^- WTI_{t-1}^- \tag{6}$$

ξ_{t-1} is the nonlinear error correction term.

$$\beta_1^+ = \frac{-\theta^+}{\rho} \; ; \; \beta_1^- = \frac{-\theta^-}{\rho}$$

$$\beta_2^+ = \frac{-\varphi^+}{\rho} \; ; \; \beta_2^- = \frac{-\varphi^-}{\rho}$$

(β_1^+, β_1^-) and (β_2^+, β_2^-): are asymmetric long-run parameters.

Third Step: Testing The null hypothesis of no co-integration in the long run between TAD_t and INF_t, WTI_t relying on the Bounds testing approach as follows:

$$\begin{cases} H_0 : \rho = \theta^+ = \theta^- = \varphi^+ = \varphi^- = 0 \\ H_1 : \rho \neq \theta^+ \neq \theta^- \neq \varphi^+ \neq \varphi^- \neq 0 \end{cases} \tag{7}$$

Similarly, we can also test the Short-run relationship as well as the Long-run relationship by testing the following hypotheses:

$$\text{Long-run: } \begin{cases} H_0 : \theta^+ = \theta^- \\ H_1 : \theta^+ \neq \theta^- \end{cases} , \begin{cases} H_0 : \varphi^+ = \varphi^- \\ H_1 : \varphi^+ = \varphi^- \end{cases} \tag{8}$$

$$\text{Short-run: } \begin{cases} H_0 : \sigma_j^+ = \sigma_j^- \\ H_1 : \sigma_j^+ \neq \sigma_j^- \end{cases} , \begin{cases} H_0 : \lambda_j^+ = \lambda_j^- \\ H_1 : \lambda_j^+ \neq \lambda_j^- \end{cases} \tag{9}$$

Fourth Step: The last step of the NARDL procedure derives the positive and negative multipliers with INF_t^+, INF_t^- and WTI_t^+, WTI_t^- computed as: (Mazorodze and Noureen, 2018).

$$mh^+ = \sum_{j=0}^{h} \frac{\partial TAD_{t+j}}{\partial INF_t^+} \text{ and, } mh^- = \sum_{j=0}^{h} \frac{\partial TAD_{t+j}}{\partial INF_t^-}$$

$$mh^+ = \sum_{j=0}^{h} \frac{\partial TAD_{t+j}}{\partial WTI_t^+} \text{ a, } mh^- = \sum_{j=0}^{h} \frac{\partial TAD_{t+j}}{\partial WTI_t^-}$$

Where h=0,1,2, for INF_t^+, INF_t^- and WTI_t^+, WTI_t^- respectively. Noteworthy is that $h\rightarrow\infty$, $m_h^+ \rightarrow \beta_i^+$ and $m_h^- \rightarrow \beta_i^- \ / i = 1,2$. These dynamic multipliers add useful information towards the analyses of the asymmetric adjustment path taken by the model following a short-run disequilibrium with initial positive or negative partial impact of crude oil prices and COVID-19 pandemic.

3. RESULTS AND DISCUSSION

As we have previously seen, applying the NARDL model requires going through the following steps:

3.1. Stationarity Study of the Series TAD_t, INF_t and WTI_t

The NARDL model requires none of the variables to be I (2). Therefore, we first perform stationary tests to make sure that none of the variables violates this condition.

To test the stationarity of series: TAD_t, INF_t, WTI_t, we rely on both the Dicky-Fuller (ADF) and Philips-Peron (PP) tests. The results can be obtained directly at the same time using the specially prepared software in Eviews 10.0.

It is clear from the results of the outputs that all series are stationary in the first degree, (I(1)), where, the calculated statistics values for the PP and ADF test for the differenced series in first degree became greater (in absolute value) than the tabular statistics in the three models at 5% level of significance (Table 1).

3.2. Bounds Test

The results above provide justification for the non-linear ARDL approach since none of the variables is I(2). The non-linear ARDL bounds testing depends on four factors (i) number of regressors (k), (ii) assumption about the intercept and trend in the cointegrating equation, (iii) number of observations (n) and (iv) whether variables are I(0) and (I(1). Here, n=318, k=4 since positive and negative changes of variables are constructed into one variable. Assumption III, intercept and no trend and I (1) variables. The non-linear ARDL bounds testing procedure is performed after the estimation of equation (4). Based on the Akaike Information Criterion (AIC), a non-linear NARDL (7, 4, 6, 0, and 6) is selected, where the hypotheses of this test are:

$$\begin{cases} H_0 : \rho = \theta^+ = \theta^- = \varphi^+ = \varphi^- = 0 \\ H_1 : \rho \neq \theta^+ \neq \theta^- \neq \varphi^+ \neq \varphi^- \neq 0 \end{cases}$$

Table 1: The results of augmented Dickey–Fuller-type test

Variable	T value
The COVID-19 pandemics	−8.7956***
Crude oil returns	−16.9656***
Stock returns	−6.0176***

*Significance at 1% level, **Significance at 5% level and *Significance at 10% level

The results of the bounds Test are summarized in the Table 2.

We note that the value of F=6.91 is greater than all the critical values at all levels of significance, implying that we cannot reject the null hypothesis. This means that stock prices index, positive and negative changes in crude oil price and COVID-19 pandemic move together in the long run.

3.3. Estimation of Model Parameters in the Long- and Short-term and Asymmetry Test

Having established the presence of a long-run relationship, the next stage involves estimating the parameters of the NARDL model in the long and short terms. But before adopting this model for use in estimating the long and short-term effects, it is necessary to ensure the quality of the performance of this model, and this is done by performing the most important diagnostic tests: Jarque-Bera test, Breusch-Godfrey Serial Correlation LM Test, ARCH Test, Ramsey RESET Test, and CUSUM and CUSUMSQ test. The results of estimating long-term parameters can be summarized in the Table 3.

From the Table 3, we can infer a negative relationship between the stock prices and the increase in the number of people infected with the pandemic, and a positive relationship between stock prices and the decrease in the number of people infected with the pandemic. There is, also, a positive relationship between positive changes in crude oil prices and stock prices. This does not respond to negative changes in crude oil prices. The error correction equation will take the following form:

$$Coint\ Eq = TAD_t - (-0{,}4021\ INF\_POS_t - 0{,}2458\ INF\_NEG_t + 25{,}0984\ WTI\_POS_t - 5{,}1791\ WTI\_NEG_t + 6193{,}73) \quad (17)$$

3.3.1. Long-run symmetry test

What is generally observed directly through the results of the estimation is the high response in stock price volume to the positive changes of the pandemic compared to the negative changes of the pandemic. As for the crude oil price variable, the stock price responds only to positive changes, since the negative changes parameter are not significant in the long term. A formal test is performed to check if the effect is really asymmetric for the two variables: INF and WTI. So, to test for long-term asymmetry, we need to test the following hypothesis based on Wald's test:

$$H_{LR1} : \begin{cases} H_0 : -c(3)/c(2) = -c(4)/c(2) \\ H_1 : -c(3)/c(2) \neq -c(4)/c(2) \end{cases} \text{ for variable } INF_t,$$

$$\text{And } H_{LR2} : \begin{cases} H_0 : -c(5)/c(2) = -c(6)/c(2) \\ H_1 : -c(5)/c(2) \neq -c(6)/c(2) \end{cases} \text{ for variable } WTIt$$

Results from the lower part of Table 3 show that the null hypothesis of long-run symmetry is rejected at 1% level. This shows the

Table 2: Non-linear ARDL bounds test results

H0	There is no cointegration between the variables		
F-Bounds Test critical values	**Pesaran et al., 2001**		**Decision**
	Upper Bound	**Lower Bound**	
Significant at 10%	2.2	3.09	The null hypothesis is rejected and accepte the alternative hypothesis.
Significant at 5%	2.56	3.49	
Significant at 1%	3.29	4.37	
F-Bounds Test critical values	**Narayan 2005**		**Dicision**
	Lower Bound	**Upper Bound**	
Significant at 10%	2.3	3.22	The null hypothesis is rejected and accept the alternative hypothesis.
Significant at 5%	3.68	3.69	
Significant at 1%	3.6	4.78	
Test Statistics	**Number of independent variables**	**(F) Statistic**	**Conclusion**
	K=4	F=6.915148	There is cointegration

Table 3: Results of estimating the long-term parameters of the NARDL model

Results of estimating the following long-run equation for the following NARDL model :

$TAD_t = \alpha + \beta_1^+ \cdot INF_t^+ + \beta_1^- \cdot INF_t^- + \beta_2^+ \cdot WTI_t^+ + \beta_2^- \cdot WTI_t^- + u_t$ **Dependent Variable:** TAD_t

Variable	Coefficient	Std.Error	t-Statistic	Prob.
INF_POS	−0.402127	0.083996	-4.787^{***}	0
INF_NEG	−0.245809	0.067337	-3.650^{***}	0.0003
WTI_POS	25.09845	6.891937	3.641^{***}	0.0003
WTI_NEG	−5.179134	11.26501	−0.459	0.646
C	6193.736	102.3311	60.52^{***}	0
Diagnostic tests	**JB**	**LM**	**ARCH**	**RESET**
Statistic	χ^2=3.54	$F_{(2,288)}$=0.96	$F_{(1,315)}$=0.41	$F_{(1,289)}$=1.98
Probalility	0.17	0.41	0.52	0.16

***Denote significant at 1%

Long-run Symmetry $F\text{-}stat_1$=9.47 $prob$=0.002

The long-run symmetry joint null hypothesis is $\frac{-\theta^+}{\rho} = \frac{-\theta^-}{\rho}$:or $\beta_1^+ = \beta_1^-$ and $\frac{-\phi^+}{\rho} = \frac{-\phi^-}{\rho}$ or $\beta_2^+ = \beta_2^-$

validity of the alternative hypothesis that the stock prices' response to Changes in the number of people infected with the COVID-19 pandemic is asymmetric. As for the symmetry test for the crude oil prices variable, it cannot be performed because the negative changes in the long-term relationship are not significant. In addition, the results of the short-term parameter estimates (results of ECM estimates of NARDL model) are as follows:

Based on the short-term model, it is notified that stock prices generally respond positively to stock prices for the past periods. Also, they generally respond positively to both positive and negative changes in the number of people infected with the COVID-19 pandemic. In addition to negative changes in the price of crude oil in general. Yet, they do not respond to positive changes in the price of crude oil.

3.3.2. Short-run symmetry test

Similarly to the previous test, we can also do a test to the Short-run relationship by testing the following hypotheses:

$$H_{SR1}: \begin{cases} H_0 : c(16) = c(17) + c(21) + c(22) \\ H_1 : c(16) \neq c(17) + c(21) + c(22) \end{cases} \text{ for variable } INF_t$$

Results from the lower part of Table 4 show that the null hypothesis of Short-run symmetry is rejected at 10% level. This result shows the validity of the alternative hypothesis that the stock prices' response to change in the number of people infected with the COVID-19 pandemic is asymmetric. As for the symmetry test for the crude oil prices variable, the test cannot be performed because the short-term model does not contain variables that represent positive change in crude oil prices.

3.4. Diagnosis of Estimate Results

In light of the previous results of the long and short equations for the previous NARDL model, we find that the error correction parameter (ECT_{t-1}) is significant at the level of 1% with the expected negative sign. This result is considered as a support to a long-term equilibrium relationship between the variables.

This parameter (−0.17) indicates that 17% of short-run disequilibrium of stock prices is corrected each day. That is, when the stock prices index deviates during the short period (t-1) from its equilibrium values in the long run, the equivalent of 17% of this deviation is corrected in the period (t). Likewise, it can be said that the stock prices index takes approximately $\frac{1}{0.17} \simeq 6$ day to adjust to its equilibrium value.

Also, the estimation results showed that most of the estimated parameters were statistically significant at varying significance levels, with the exception of variables $D(TAD_{t-4})$, $D(TAD_{t-6})$, $D(\text{INF\_}POS_t)$, $D(INF\_POS_{t-1})$, $D(INF\_POS_{t-2})$, $D(INF\_NEG_{t-1})$, $D(INF\_NEG_{t-2})$, $D(WTI\_NEG_t)$ in the short run.

Table 4: Results of estimating the short-term parameters of the NARDL model

Results of estimating the short-term equation for the following NARDL model:

$$D(TAD_t) = \sum_{i=1}^{p} \gamma_i \cdot D(TAD_{t-i}) + \sum_{i=0}^{q} \left(\sigma_i^{+} \cdot D(INF_{t-i}^{+}) + \sigma_i^{-} \cdot D(INF_{t-i}^{-}) \right) + \sum_{i=0}^{k} \left(\lambda_i^{+} \cdot D(WTI_{t-i}^{+}) + \lambda_i^{-} \cdot D(WTI_{t-i}^{-}) \right) - \rho \cdot ECT_{t-1} + \varepsilon_t$$

$$D(UNTC_t) = \underset{(2,44)^{**}}{0,13} \cdot D(TAD_{t-1}) - \underset{(-1,86)^{*}}{0,1} \cdot D(TAD_{t-2}) + \underset{(4,11)^{***}}{0,22} \cdot D(TAD_{t-3}) + \underset{(1,17)}{0,06} \cdot D(TAD_{t-4}) + \underset{(3,14)^{***}}{0,17} \cdot D(TAD_{t-5}) + \underset{(1,43)^{***}}{0,07} \cdot D(TAD_{t-6})$$

$$+ \underset{(0,2)}{0.01} \cdot D(INF\_POS_t) - \underset{(-0,4)}{0,02} \cdot D(INF\_POS_{t-1}) - \underset{(-0,06)}{0,004} \cdot D(INF\_POS_{t-2}) + \underset{(2,72)^{***}}{0,16} \cdot D(INF\_POS_{t-3}) - \underset{(-2,69)^{***}}{0,17} \cdot D(INF\_NEG_t)$$

$$+ \underset{(0,68)}{0,04} \cdot D(INF\_NEG_{t-1}) - \underset{(-0,62)}{0,04} \cdot D(INF\_NEG_{t-2}) - \underset{(-1,64)}{0,1} \cdot D(INF\_NEG_{t-3}) - \underset{(-2,49)^{**}}{0,14} \cdot D(INF\_NEG_{t-4}) + \underset{(2,49)^{**}}{0,14} \cdot D(INF\_NEG_{t-5})$$

$$- \underset{(-0,23)}{1,44} \cdot D(WTI\_NEG_t) - \underset{(-1,77)^{*}}{11,01} \cdot D(WTI\_NEG_{t-1}) - \underset{(-1,9)^{*}}{11,65} \cdot D(WTI\_NEG_{t-2}) - \underset{(-2,26)^{**}}{13,98} \cdot D(WTI\_NEG_{t-3}) - \underset{(-1,73)^{*}}{10,97} \cdot D(WTI\_NEG_{t-4})$$

$$- \underset{(-1,98)^{**}}{12,48} \cdot D(WTI\_NEG_{t-5}) - \underset{(-6,49)^{***}}{0,17} \cdot ECT_{t-1}$$

$$R^2 = 0,24 \quad Loglikelihood = -1891,56 \quad DW = 1,93 \quad n = 318$$

The index (D) attached to all variables represents the difference in the first degree; : Error correction term; *, **, ***Represents the statistical significance at 10.5 and 1%, respectively. The values in parentheses represent the values of Student's stats

Long-run Symmetry $F\text{-}stat_1$=3.44 *prob*=0.06

The long-run symmetry joint null hypothesis is: , $-\sum_{i=j+1}^{q} \theta_j^{-} \quad -\sum_{i=j+1}^{q} \theta_j^{+}$

It is also clear from the table that the value of the determination coefficient reached 0.24. This means that variations in crude oil price and COVID-19 pandemic account for the 24% of the change in stock prices index. This is a low value, which indicates the model's poor goodness fit. In addition, the Durbin-Watson statistic does not suggest autocorrelation errors of the first degree.

Finally, it appears clearly from the lower part of table 3 show that none of the relevant diagnostic tests was violated. In particular, the model does not suffer from autocorrelation of degree greater than 1, heteroscedasticity, model misspecification, residual non-normality and parameters instability as shown in the following figures 1 and 2:

Figure 1: CUSUM test

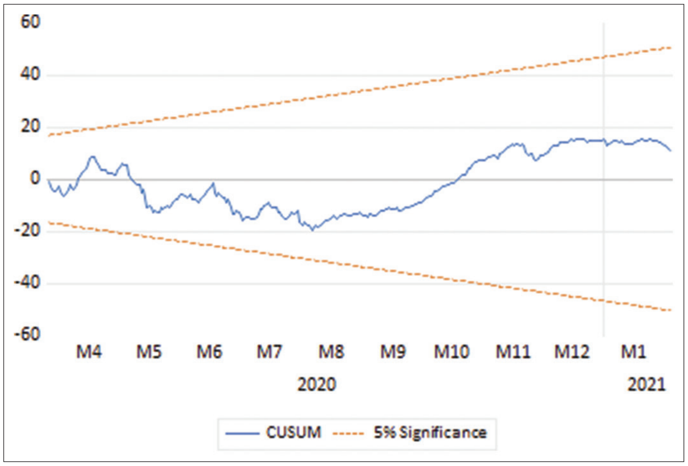
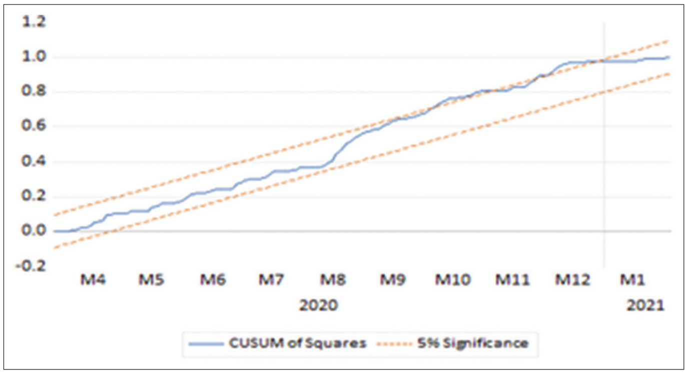


Figure 2: CUSUM of squares test



From these two figures, it is clear that the estimated coefficients of the model are structurally stable over the period under study.

3.5. Multiplier Effect Analysis

The last step when estimating the NARDL model is to derive asymmetric cumulative dynamic multipliers that allow us to trace out the asymmetric adjustment patterns following positive and negative changes in COVID-19 pandemic variable, and crude oil price respectively. The following figures synthesizes this analysis:

This Figure 3 shows that the stock prices index responds positively to negative changes in the number of people infected with COVID-19 pandemic and negatively to positive changes during the entire study period.

We also note that the stock price index responds with a larger size to negative changes in the number of people infected with the pandemic, compared to positive changes until the twelfth period. In this context, we note that the asymmetry curve (asymmetry chart: which represents the difference between the stock price index response to positive and negative changes in the number of people infected with the COVID-19 pandemic) takes a positive sign until day 12, but after this period it becomes negative. Therefore, the asymmetry curve indicates that the stock price index's response to

Figure 3: Dynamic multipliers for INF_t in KSA. Source: Prepared by researchers using the Eviews 10.0 program

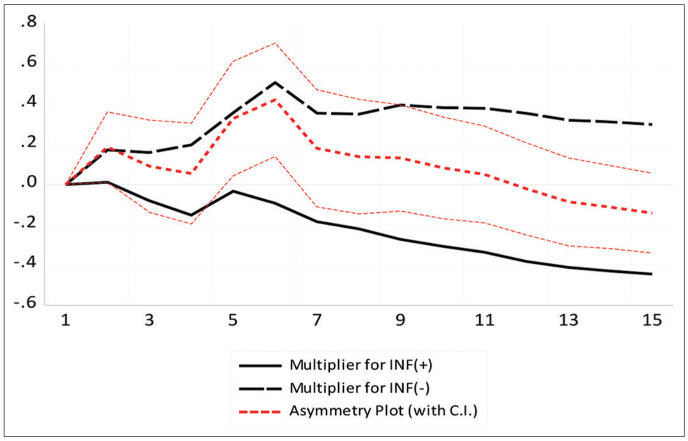
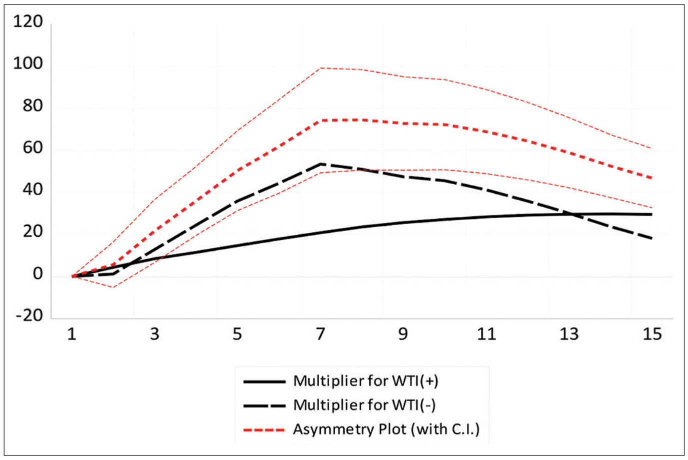


Figure 4: Dynamic multipliers for WTI_t in KSA



positive changes in the number of infected people becomes greater than the price index's response to negative changes.

It should also be noted that the increase in the number of people infected with the pandemic takes about 15 days until it is completely converted to the level of the stock price index and converges with the long-term coefficient (which equals −0.4) for positive values and (−0.24) for negative values.

The Figure 4 shows that the stock price index responds positively to both positive and negative changes in crude oil prices during the entire study period. There, it appears that the asymmetry curve (asymmetry Plot) takes a positive sign during the whole study period.

We also note that the stock price index's response to negative changes in crude oil prices is stronger than the response to positive changes until day 13, after which it becomes the opposite.

In general, these multiplier effects of positive and negative changes in the two variables (number of people infected with the pandemic and the crude oil prices) are logical and consistent with economic theory and previous studies. Indeed, the positive shocks in the number of people infected with COVID-19 lead to a decrease in the stock price index, while negative shocks increase it. In addition, the multiplier effects of positive shocks in the number of people infected with COVID-19 are stronger than the multiplier effects of negative shocks at the end of the period (i.e., in the long term). In this line, the asymmetry plot shifts down towards the multiplier curve of the positive effects, which indicates a decrease in the stock price index on the long term overall. This confirms the results of estimating the long-term equation presented in Table 4.

On the other hand, we find that there are positive responses to the stock price index for both positive and negative shocks in crude oil prices during the study period, which violates the economic theory, due to the decrease in the study period taken into account in calculating the size of the multiplier effects (15 days only). It should be noted, also, that the stock price index responds to negative shocks in crude oil prices in the long term.

4. CONCLUSIONS AND POLICY IMPLICATIONS

In this paper, we investigate the relationship between the crude oil market, stock market and COVID-19 pandemic in the case of KSA. The study uses monthly data from March 15, 2020 to February 03, 2021. The nonlinear autoregressive distributed lag model developed by Shin et al., (2014) is applied to investigate the nonlinear influence of COVID-19 pandemic and crude oil market on stock market in KSA both in the long and short run.

In the long-term, we note that the coefficient of the variable that represents positive changes in the number of people infected with COVID-19 is negative and significant at 1% level. The interpretation of this coefficient is that the stock prices Index falls by 0.4 points in the long run if the number of people infected with COVID-19 increases by one unit. In addition, the coefficient associated with the negative changes of the number of people infected is negative and significant at 1% level. The interpretation of this coefficient is that a reduction in the number of people infected with COVID-19 by one unit raises the stock prices Index by 0.24 points in the long run. This result clearly indicates that the stock price index in Saudi Arabia does not respond with the same value to both the decrease and the increase in the number of infected people. This result was similar to the result of (Anh and Gan, 2021; Al-Awadhi et al., 2020; Alfaro et al., 2020; Eleftheriou and Patsoulis, 2020; He et al., 2020; Zhang et al., 2020).

On the other hand, we note that the coefficient of positive crude oil prices changes is positive and significant at 1% level. The interpretation of this coefficient is that the stock price index rises by 25.09 points in the long term if positive crude oil prices increase by one unit. As for the variable that represents the negative changes in crude oil prices, it is not statistically significant. This result clearly indicates that the stock price index in Saudi Arabia responds only to positive changes in crude oil prices in the long term.

It is clear from the long-term results that the impact of crude oil prices is large compared to the variable that represents the number of individuals infected with COVID-19. The small size of the impact of the variable that represents the number of people infected with the COVID epidemic can be attributed to the success of the Kingdom of Saudi Arabia in limiting the spread of the COVID-19 epidemic. The decrease in the number of injured and deaths and the application of strict protocols, as well as the great support for government and private institutions to reduce the impact of the epidemic on them, contribute to reducing its impact on the Saudi financial market, on the other hand. The impact of the decline in oil prices was the greatest due to the high dependence of the Saudi domestic product on oil revenues.

From the above short-term model, we notice a positive and significant effect of the stock price index for the last period and retarded with three and five periods (days) on the current stock price index, where impact size reached 0.13, 0.22, 0.17, respectively. Moreover, an inverse and significant relationship between the current stocks price index and the delayed one in two periods (two days), where the effect size was −0.1. This relationship shows an important fact: the dynamic nature of the stock price index. This means that the stock price index in the current period depends on the stock price index in previous periods (this is known in economics as the stock price index hysteria).

The results indicate that a variable representing positive changes in the number of people infected with COVID-19 that is 3 days late and is considered statistically significant at only 1% in the short term. The interpretation of this coefficient is that an increase in the number of people infected with COVID-19 retarded by 3 days by one unit will raise the stock price index by 0.16 points in the short term.

The results indicate that there is a positive and significant relationship between the stock price index and the variable represented by negative changes in the number of people infected with COVID-19 and retarded by 2 and 4 days. The interpretation of these coefficients is that reducing the number of individuals infected with COVID-19 that is delayed by two and four periods by one unit will raise the stock price index by 0.04 and 0.14 points, respectively, in the short term. Moreover, there is an inverse and significant relationship between the stock price index and the negative changes in the number of people infected with the COVID-19 virus retarded by 5 days. Indeed, if this latter rises by one unit, the stock price index will fall by 0.14 points in the short term.

Finally, the short-term results indicate that the stock price index responds only to negative changes in crude oil prices and does not respond to positive changes. In general, there is a positive and significant relationship between the stock price index and the negative changes in crude oil prices at all late periods. Indeed, if the late crude oil prices decreased by 1, 2, 3, 4, 5 days by one unit, the index of the stock price will rise by 11.01, 11.64, 13.98, 10.97, and 12.48 respectively, This is in line with most of the previous studies.

Noteworthy is that the positive relationship between crude negative oil prices changes and stock price index confirmed in Table 4 (Short run model) contrasts with many other relevant studies. The difference could be emanating from the fact that they assumed linearity and symmetry.

Overall, our main result is consistent with previous studies that confirm the linearity of the relationship between crude oil prices and stock price index. Indeed, in the long term, despite the presence of asymmetry, the coefficient of negative changes in crude oil prices was insignificant, and in the short term, the stock price index is not affected by positive changes in crude oil prices.

We clearly note that the size of the impact of crude oil prices on the stock price index is much greater than the size of the impact of the development of the number of people infected with the pandemic on the stock price index in the long and short term.

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