

Asymmetric Modelling of COVID-19 related news persistence impact on Saudi Arabia stock market volatility

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ABSTRACT

This paper investigates the persistence impact of the COVID-19 related news on the volatility of the Saudi Arabia stock market based on daily time series data consists of closing prices of 21 industry groups that constitute the Saudi stock market as well as the main market for the period from 4th August 2019 to 21st May 2020 by running the EGARCH model. The empirical findings showed that the Saudi Arabia market was significantly affected during the nine trading days after the first case in Saudi Arabia. Moreover, the EGARCH model estimates supported the existence of asymmetric effect on the Saudi stock market with a 25% negative (leverage effect) and 14% positive effects. It was discovered that the Saudi stock market showed evidence of volatility persistence for the main market index and the majority of the industry groups. This paper contributes to the existing literature on the impact of COVID-19 related news on stock returns volatility. To our knowledge, similar studies are absent in the literature about Saudi Arabia. This study used the EGARCH model, which is considered the most reliable analysis technique to investigate this cloudy subject.

Keywords: Unit root, Leverage effect, ARCH effect, Stock returns, EGARCH model.

Mathematics Subject Classification : 62M10, 62J05

Journal of Economic Literature (JEL) Classification : F47, C32, M31, M20

1. INTRODUCTION

The Saudi Ministry of Health confirmed on 2nd March 2020, the first case in the country. Up to 9th March 2020, only imported cases were reported in KSA. On 10th March 2020, with 20 COVID-19 cases and five new confirmed cases, local transmission was documented. As of 26th July 2020, approximately a total of 267000 confirmed COVID-19 cases and over 2700 deaths in KSA. The Saudi government has responded boldly and swiftly to the COVID-19 pandemic and has been very active in communicating with the public through social media awareness campaigns. It has set up various support systems, including call centers and medical care for all affected, regardless of residency status. Saudi Arabia has also taken strict measures to contain the spread of COVID-19 and has implemented partial and complete curfew, domestic and international travel restrictions, suspending prayers at mosques, the closure of all schools and universities, and suspending government and private employees' attendance at workplaces.

Volatility, which defines as the spread of outcomes of a variable, plays a crucial role in stock market operations. It estimates the value of market risk. Furthermore, volatility is an essential parameter for pricing financial assets. Hence, it is crucial for assessing the current value of derivatives and forecasting their future values, which is essential for portfolio selection and management. Forecasting financial market volatility is necessary for portfolio selection and asset management as well as for the pricing of primary and derivative assets. In addition to that, many researchers agree that volatility is predictable in many asset markets see, for example, the survey by Bollerslev *et al.* (1992). Over the last few years, volatility modelling of stock market returns has become an important area. It has been attracting the attention by financial markets participants, academia, economic analysts and the general public. The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are usually used to assess the volatility by specifying the conditional mean and variance equations (Engle, 1982; Bollerslev, 1986). However, the tradition symmetric of GARCH models is to integrate the clustering volatility and leptokurtosis in a series, that is defined as a big shock followed by big or small shocks regardless of their volatility due to directional effects (Timmer, 2018), and cannot account for leverage effect or does not integrate the impact of favorable or unfavorable news on volatility risk. Asymmetric volatility is the tendency for good news to increase returns volatility than bad news of the same magnitude (Black, 1976; Christie, 1982; Nelson, 1991). Various extended models of GARCH have been proposed to capture the asymmetric behavior of the volatility of returns in addition to symmetric one. For instance, EGARCH model (Nelson, 1991), Threshold GARCH model (Zakoian, 1994), Power GARCH model (Ding *et al.*, 1993) and GJRGARCH model (GLOSTEN *et al.*, 1993).

This study investigates the persistence impact of the COVID-19 related news on the volatility of the Saudi Arabia stock market based on daily time series data consists of closing prices of twenty-one industry groups that constitute the Saudi stock market for the period from 4th August 2019 to 21st May 2020. It uses the symmetric and asymmetric models of the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) to meet its goals.

The remaining paper is arranged in the following manner: Section 2 discusses the related theoretical and empirical literature and, Section 3 explains the data and sample construction, Section 4 outlines the methodology, Section 5 outlines the descriptive statistics analysis for stock returns series and preliminary tests. Section 6 analyzes the empirical findings, and Section 7 concludes the study.

2. LITERATURE REVIEW

The COVID-19 pandemic represents a significant shock to the global economy. Indeed, this pandemic presents a severe challenge to economic development worldwide, and it is expected to blanket the globe (Goodell, 2020).

Most world countries took bold quarantine and lock-down measures to prevent the explosion of the epidemic. The economic consequences of the pandemic spread were vital and came through both supply and demand-side channels. Many studies were conducted on the economic impacts of the COVID-19 outbreak on supply and demand sides, financial markets, the labor market, and food security. Different methodologies were used; many series of data were utilized to have a clear overview of COVID-19 economic and financial impacts. The Event study, Panel analysis, Markov-Switching, and GARCH family methods of analysis adopted in a wide range of previous studies related to the COVID-19 outbreak; therefore, reviewing these analysis methods is essential to forecast and analyze the impact of COVID-19 more effectively. The mentioned analytical methods and their findings are summarized in Table 1. In contrast, studies using GARCH family models are demonstrated in Table 2.

Table 1. Review Studies that used The Event study, Panel analysis and Markov-Switching to assess the economic impact of COVID-19 outbreak

Author(s) (year)	Study objective	Method of analysis	Key findings
Heyden and Heyden(2020)	Investigates cross-country U.S. and European stock market reactions to the arrival and containment of COVID-19	Event Study	The announcement of fiscal policy measures has strongly negative effects on stock returns, whereas monetary policy measures have the potential to ease stock markets.
Liu et al. (2020)	To evaluate the short-term impact of the coronavirus outbreak on 21 leading stock market indices in major affected countries.	Event Study	The stock markets in major affected countries and areas fell quickly after the virus outbreak. Countries in Asia experienced more negative abnormal returns as compared to other countries.
GÖKER et al. (2020)	To analyze the impact of the COVID-19 outbreak on the Borsa Istanbul sector index returns.	Event Study	Most of the sectors have negative cumulative abnormal returns. The highest lost is found in the Sports, Tourism and Transportation sectors.
Alber(2020)	To investigate the effects of Coronavirus spread on stock markets in most affected six countries.	Panel, GMM	Stock market returns are sensitive to Coronavirus cases more than deaths, and to Coronavirus cumulative indicators more than new ones.
ÖZTÜRK et al. (2020)	To analyze the effects of the outbreak on the Turkish stock market.	Panel, Fixed-effect	Sectoral indices were affected by the number of cases reported in Turkey than the number of cases in Europe and in the world.
Al-Awadhi et al.(2020)	To study whether contagious infectious diseases (Covid-19) affect stock market outcomes in the Shanghai Stock Exchange.	Panel, Regression	Both the daily growth in total confirmed cases and in total cases of death caused by COVID-19 have significant negative effects on stock returns across all companies.
Mishra et al. (2020)	To investigate the impact of COVID-19 on Indian financial market and compared with the outcomes of two recent significant structural changes of the Indian economy such as demonetization and implementation of a tax rate.	Markov-Switching VAR	The impact of COVID-19 is severe on stock returns in comparison to the effect of demonetization and the Tax.
Onali (2020)	To examine the impact of Covid-19 cases and related deaths on the U.S. stock market (Dow Jones and S& P500 indices)	Markov-Switching with GARCH	At the end of February 2020, the magnitude of the negative impact of the VIX on stock market returns increased threefold.
Yarovaya et al.(2020)	To analyze herding in cryptocurrency markets in the time of the COVID-19 pandemic.	Markov-Switching	In all markets studied, herding remains contingent on up or down markets days but does not get stronger during the COVID-19.
Sayed and Eledum(2021)	To explore the short-term response of the Saudi stock market to the COVID-19.	Event Study	The most negatively affected industry groups were banks, consumer services, capital goods, transportation and commercial services, while telecom. serv. and food and beverage were positively affected at the event window (+1, +9).

Table 2. Review Studies that employed symmetric and asymmetric GARCH family to assess the economic impact of COVID-19 outbreak.

Author(s) (year)	Study objective	Method of analysis	Key findings
Ejem and Ogbonna (2020)	To evaluate volatility persistence and examining the asymmetric effect on the Nigerian capital market.	EGARCH	The negative shocks increase volatility more than positive shocks of the same magnitude.
Liew et al. (2020)	To quantify the effect of the deadly novel coronavirus (COVID-19) pandemic outbreak on Chinese stock market performance.	EGARCH	Health care, information technology and Telecommunication services sectors were relatively more pandemic resistant, while the pandemic outbreak more severely hurt other sectors
Ozdurak et al. (2020)	To examine whether COVID-19 related news triggers investment to pharma and biotech companies.	EGARCH	The asymmetry for the favour of good news suggests that the market prices companies like Gilead and Dynavax with an expectation to find the cure or play an essential part in this process.
Adenomon et al. (2020)	To assess the possible impact of Coronavirus on the Nigerian financial market and economy.	EGARCH and OGARCH	They are revealing a negative impact of COVID-19 on the stock returns in Nigeria under the period of study.
Alan et al. (2020)	To investigate the impact of COVID-19 pandemic on market volatility.	GJR-GARCH	The daily number of active cases and the Curvature are significant predictors of a daily cross-section of both realized volatility and the GJR-GARCH volatility in global equity markets over the test period.
Benzid and Chebbi(2020)	To investigate the impact of COVID-19 cases and related deaths in the U.S. exchange rate volatility.	EGARCH	An increase of the number of cases and the deaths (both in logs) in the U.S. has a positive impact on the USD/EUR, USD/Yuan and USD/LivreSterling.
Gunay (2020)	To examine the influence of the COVID-19 pandemic on six different stock markets.	DCCMVGARCH and DCC-MVFIGARCH	All stock markets exhibited structural breaks Electronic copy available.
Su and Zhong (2020)	To build an index of policy effectiveness on fighting COVID-19 pandemic.	DCC-GARCH	The policy effectiveness of central government documents is highly significant, although the time lag and power between central and local varies.

This paper contributes to the existing body of literature on volatility modelling in the following aspects. First, many studies employed GARCH family methods without doing diagnostic tests, which are designed to determine whether the technique is an appropriate one. In this study, we apply four different tests to determine the proper method for attaining the objective. The most important of these tests is the Engle and Ng test, which checks the asymmetric volatility effect and considers it a necessary condition for using EGARCH. Second, the data's distribution shapes lead to the application of three different distributions (normal, t-Student, and generalized error distribution (GED)) to model the volatility returns of industry groups and main market in Saudi Arabia.

3. SAMPLE CONSTRUCTION

The raw data⁽¹⁾ used in this study consist of 205 daily market observation from 4th August 2019 through 21st May 2020, including the closing prices of 21 industry groups in the stock market of Saudi Arabia as well as the main market index (TASI), which were obtained from Saudi Arabia stock market (TADAWUL) and investing.com website. The stock market of Saudi Arabia is open from Sunday to Thursday. The number of confirmed cases from COVID-19 in Saudi Arabia over the same period were also collected from Saudi Arabia ministry of health website. Moreover, we collected data from other financial markets such as the commodity markets represented by spot gold price (G.P.) and closing prices of major stock market indexes for New York (S&P 500 index) and used them for control purposes. Daily financial and commodity variables are obtained from Investing.com. We used the common trading window procedure and removed the data for those dates when any series has a missing value due to no trading and used the geometric mean measure to overcome different trading days between Saudi Arabia and other countries. The calculations were done using Excel and EViews 10. The daily returns R_t are calculated as:

$$R_t = \ln(P_t) - \ln(P_{t-1}) \quad (1)$$

where R_t denotes the stock returns series, and P_t is the closing stock price at the current day t . Table A.1 in the Appendix shows the stock returns and its corresponding industry groups or market index.

4. METHODOLOGY

To investigate the persistent impact of the COVID-19 related news on the Saudi Arabian stock market's asymmetric volatility, we employ the EGARCH methodology proposed by Nelson (1991). The EGARCH model considers as one of the popular methods used to capture the asymmetric effects between positive and negative stock returns. The EGARCH model analyses involve the joint estimation of two equations, one for the conditional mean and the other for the conditional variance. The mean equation describes the mean of the time series; it is a linear regression function that contains a constant and possibly some explanatory variables, while the variance equation explains how the error variance behaves. The EGARCH (1,1) model is developed for identification of the relationship between stock returns and some explanatory variables in the mean equation and given as,

$$R_t = \beta_0 + \beta_1 CNCS_t + \beta_2 CD_t + \beta_3 VD_t + \beta_4 ND_t + \beta_5 HD_t + \beta_6 LD_t + \beta_7 GP_t + \beta_8 SP_t + \epsilon_t; \quad t = 1, 2, \dots, 205 \quad (2)$$

where R_t represents the observed returns of each industry group and the main market on day t . $CNCS$ is the daily new confirmed cases in Saudi Arabia, CD is the China dummy variable assumes a value of 1 for observations ranging from 2 to 27th February 2020, and zero otherwise, VD is the COVID-19 dummy variable specifies a value of 1 for observations ranging from 2nd March 2020 to 21st May 2020, and zero otherwise. ND is the nine trading days dummy variable assigns a value of 1 for observations ranging from 3 to 15th March 2020, and zero otherwise, HD is the dummy variable assumes a value of 1 for observations ranging from 16 to 25th March, and zero otherwise, LD is lock-down dummy variable assumes a value of 1 for observations ranging from 26th March 2020 to 23rd April 2020, and zero

¹ The data that support the findings of this study are openly available in:

(a) Tadawul site at <https://www.tadawul.com.sa/wps/portal/tadawul/home?locale=en>

(b) Investing.com site at <https://www.investing.com/>

(c) Saudi Arabia ministry of health website: <https://www.moh.gov.sa/en/Pages/default.aspx>.

otherwise (see, Table 3). GP , SP is the spot gold price and stock returns for the S&P 500 index respectively, which constitute together the control variables. Further, β_i for $i = 1, 2, \dots, 8$ are the parameters to be estimated, and ϵ_t is the error term which we assume to follow different distributions, namely normal, t-student and generalized error distributions.

It is expected that the Saudi Arabia stock market is adversely affected by the COVID-19 pandemic in general, so the estimated values of the coefficients $\hat{\beta}_i$ for $i = 2, 3, \dots, 6$ should be negative, for lower index price during these periods. On the other hand, CNCS indicates the condition of the coronavirus outbreak with higher (lower) value means more (less) confirmed COVID-19 cases in Saudi Arabia. A rational investor would take less cases as favorable news of improving condition and more cases as a deteriorating condition. Thus, $\beta_1 < 0$ is expected. The conditional variance equation for EGARCH (1,1) model specification is given as:

$$\ln(h_t) = \omega + \alpha \cdot \frac{|\epsilon_{t-1}|}{\sqrt{h_{t-1}}} + \gamma \cdot \frac{\epsilon_{t-1}}{\sqrt{h_{t-1}}} + \lambda \cdot \ln(h_{t-1}) \quad (3)$$

where $\ln(h_t)$ is the natural log of the conditional variance (one period ahead volatility forecast); ω , α , γ and λ are constant parameters. ω is the mean level, α is the volatility clustering coefficient, also called the symmetric effect, λ is the persistence parameter, γ is the leverage effect which represents the asymmetric coefficient in the model. $\epsilon_{t-1} > 0$ and $\epsilon_{t-1} < 0$ implies good news and bad news and their total effects are $(1 + \gamma)|\epsilon_{t-1}|$ and $(1 - \gamma)|\epsilon_{t-1}|$ respectively. When $\gamma < 0$, we expect that bad news would have a higher impact on volatility. Failing to accept the null hypothesis that $\gamma = 0$ shows the presence of leverage effect, that is bad news have stronger effect than good news on the volatility of stock index returns (Atoi (2014)).

Table 3. The events are corresponding to the Dummy variables and justifications.

No.	Dummy variable	Period	Justification of event Determination
1	CD	2 – 28 Feb	Several sporting, cultural and entertainment events were cancelled. Moreover, Saudi suspended the Umrah mass gathering for the first time in many decades.
2	V.D.	2 nd March – 21 st May	Period of COVID-19.
3	ND	3 – 15 Mar	the Saudi Ministry of Education declared the closure of schools, universities and other institutions, further suspension of events and celebrations, conference and sporting activities.
4	H.D.	16 -25 Mar	Authorities instruct people to pray in their homes. The Kingdom's Two Holy Mosques in Makkah and Medina were also temporally closed for the public. They also suspended all domestic public transport, flights, trains, buses, and taxis.
5	L.D.	26 th March to 23 rd April	The Saudi Authorities declared a partial curfew in the Kingdom as of 23 rd March 2020. Significant penalties backed the curfew for breaking it.

5. DESCRIPTIVE STATISTICS AND PRELIMINARY TESTS

This section outlines the descriptive analysis for the series of stock returns of the industry groups and main market as well as conducts the preliminary tests applied for each series.

5.1. Descriptive statistics

We report the descriptive statistics such as Mean, Standard Deviation, Skewness, and Kurtosis of the stock returns for the 21 industry groups and the main market in Table 4; further, this table also provides the Jarque-Bera test for normality. Table 4 reveals negative means daily returns for most of the industry groups as well as the main market within the period of study. In contrast, five industry groups have positive means: Food & Staples Retailing, Pharmacy, Biotech & Life Science, Software & Services, Energy and Food & Beverage. Moreover, standard deviations that measure the underlying assets' riskiness were ranging from 0.44% to 1.17%. The higher the standard deviation, the higher the market volatility, and the riskier the equity traded. Further, considering the very high Jarque-Bera values and the very small corresponding p-values, the null hypotheses of normality were rejected for the overall stock returns variables. These results supported by the values of skewness (-2.025 to -0.0268) are less than 0 (skewness of a normal distribution is 0), and the values of kurtosis (5.937 to 13.932) are higher than 3 (kurtosis of a normal distribution is 3). The negative skewness is an indication that the lower tail of the distributions is thicker than the upper tail meaning that the stock returns drop more often than it rises, reflecting the unconfidently in the market. Information emanating from the descriptive statistics supports the subjection of the return's series to volatility models.

Table 4. Summary Statistics for Stock returns variables.

Stock returns	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	p-value
R1	0.000640	0.009727	-0.0268760	7.422593	167.0939	0.0000000
R2	-0.0004010	0.008217	-0.7671100	9.303810	359.5345	0.0000000
R3	-0.0005680	0.007976	-1.4142950	11.80911	731.1776	0.0000000
R4	-0.0001370	0.007028	0.029125	6.808527	123.9248	0.0000000
R5	0.000112	0.008530	-0.1656490	13.93252	1021.837	0.0000000
R6	-0.0003470	0.007574	-1.6961770	13.15683	979.4667	0.0000000
R7	-0.0008460	0.011724	-0.1325460	5.936507	74.25565	0.0000000
R8	-0.0006330	0.008025	-1.5192630	9.654077	457.0593	0.0000000
R9	-0.0000169	0.007733	-1.0058450	10.22635	480.6140	0.0000000
R10	7.65E-06	0.010809	-0.4811870	7.922331	214.8699	0.0000000
R11	-0.0002570	0.009020	-1.5117180	9.483040	437.0854	0.0000000
R12	-0.0004950	0.008046	-1.4635590	12.79818	893.2225	0.0000000
R13	-0.0001650	0.007423	-0.5774220	10.03163	433.7238	0.0000000
R14	-0.0002680	0.008499	-2.0250800	11.83178	806.3682	0.0000000
R15	-0.0002740	0.007874	-0.9083830	9.272063	364.2117	0.0000000
R16	-0.0001310	0.004361	-1.6469480	10.51320	574.8363	0.0000000
R17	0.000228	0.007092	-0.2905770	12.65214	798.6592	0.0000000
R18	-0.0002970	0.007613	-0.3845180	6.115252	87.94680	0.0000000
R19	-0.0004720	0.008132	-1.3198070	10.37289	523.8351	0.0000000
R20	-0.0002100	0.009181	-1.6984660	10.26679	549.6168	0.0000000
R21	0.000261	0.007393	-0.6807170	10.64820	515.4764	0.0000000
RM	-0.0004370	0.007161	-1.4610170	11.58189	702.0150	0.0000000

5.2. Preliminary tests

5.2.1. Unit root test

To check whether the regression model's main variables are stationary, we carried on ADF root test. The ADF test results in Table A.2 in the Appendix show that all variables are stationary with constant and trend at level throughout the study period; therefore, the regression can be done.

5.2.2. Heteroscedasticity test

One of the most important issues before applying the GARCH models, especially EGARCH methodology, is to first examine the residuals for the evidence of heteroscedasticity. To test whether the residuals in the model (2) exhibit no Autoregressive conditional heteroscedasticity, Lagrange Multiplier (lm) test is used. The results in Table A.3 in Appendix indicate the presence of ARCH effects (except R1 variable) in residuals of the models include each dependent variable of 21 industry groups returns as well as the main market returns; consequently, these results allow us to estimate the GARCH models in general.

5.2.3. Engle and Ng test

The presence of ARCH effect in the model is considered a sufficient condition for applying the EGARCH model, while the existence of asymmetric volatility effect is necessary. Two reasons to estimate some asymmetric GARCH models which EGARCH one of them; first is to see if there is sign bias, which investigates whether positive and negative shocks have a different impact upon future volatility; second is to see if there is size effect, which examines whether the magnitude of shock also affects the future volatility. The Engle and Ng test proposed by Engle and N.G. (1993) used to determine the existence of the sign bias or size bias in the volatility of the returns. If anything significant is found from the test, this a reasonable justification for estimating the EGARCH model. Table 5 summarizes the results obtained by Engle and Ng Test. Based on this table, we observe that all stock returns variables have either sign or size bias or both except R1, which failed to pass the ARCH effect. Consequently, EGARCH methodology can be used to model the volatility of these stock returns variables.

Table 5. The existence of sign bias and size bias in the volatility of stock returns

Stock returns	Sign bias	Size bias	Stock returns	Sign bias	Size bias
R1	X	X	R12	√	√
R2	X	√	R13	X	√
R3	X	√	R14	X	√
R4	√	√	R15	√	√
R5	X	√	R16	X	√
R6	X	√	R17	X	√
R7	X	√	R18	X	√
R8	X	√	R19	X	√
R9	X	√	R20	X	√
R10	√	√	R21	√	√
R11	X	√	Rm	X	√

6. ANALYSIS AND RESULTS

This section first summarizes the criteria used to select the appropriate model within the three distributions of the error term and discusses the results obtained from the application based on that.

6.1. Model selection

The first order volatility model in Eq.(3) is estimated by allowing the error term ϵ_t in the mean model of Eq.(2) for the variance equation to follows normal (ND), students' t (STD) and generalized error (GED) distributions. This process generates 63 volatility models. Model selection is made using logL, SIC and AIC criteria, and the model with least LogL, SIC and AIC values across the error distributions is considered the best fitted. This selection produces the best suited conditional variance model for each of the 21 stock returns. Table 6 displays the distribution of error term, LogL, SIC and AIC for the best model corresponding to each stock returns.

Table 6. Error term distribution, logL, SIC and AIC for the best model corresponding to each stock returns

no	Stock returns	Distribution	LogL	AIC	SIC	No.	Stock returns	Distribution	LogL	AIC	SIC
1	R2	STD	793.357	7.603	7.377	12	R13	ND	770.610	7.391	7.181
2	R3	ND	772.231	7.407	7.196	13	R14	ND	745.654	7.148	6.937
3	R4	ND	742.498	7.117	6.906	14	R15	STD	757.418	7.253	7.026
4	R5	ND	739.845	7.091	6.880	15	R16	ND	877.173	8.431	8.220
5	R6	ND	757.077	7.259	7.049	16	R17	ND	767.959	7.365	7.155
6	R7	ND	643.534	6.152	5.941	17	R18	GED	739.385	7.077	6.850
7	R8	ND	730.553	7.001	6.790	18	R19	ND	747.841	7.169	6.958
8	R9	GED	754.758	7.227	7.000	19	R20	GED	736.104	7.045	6.818
9	R10	ND	679.211	6.500	6.289	20	R21	ND	752.503	7.215	7.004
10	R11	GED	726.004	6.946	6.719	21	Rm	ND	767.845	7.364	7.154
11	R12	ND	748.517	7.176	6.965						

6.2. Empirical results

The presence of ARCH effect and asymmetric volatility gave credence to estimating the EGARCH model with the three error distributions to determine the best volatility forecasting model. Tables 7 and 8 demonstrate the results of the 21 parameters estimates of the models (2) and (3), respectively. Moreover, the least-squares method used to estimate the model of Eq. (2) where the returns of Food & Staples retailing industry group (R1) considers as a dependent variable, the resulting model which demonstrates in Table 9 shows that, since all estimated coefficients of the COVID-19 explanatory variables in the regression equation are insignificant, therefore, Food & Staples retailing industry group is insignificantly affected by the announcement of COVID-19 in Saudi Arabia.

Table 7. Estimated EGARCH models: Mean Equation

CNCS	CD	VD	ND	HD
-6.43E-06**	-0.0015	0.0141**	-0.0235***	-0.0195***
-1.09E-06	-0.0011	-0.0004	-0.0111***	0.0011
-2.68E-06	-0.0011	0.0100*	-0.0104**	-0.0082
-5.51E-07	0.0003	0.0003	-0.00377	0.0102***
1.92E-06	-0.0009	-0.0066**	-0.0044	0.0066
-5.15E-06	-0.0007	0.0123**	-0.017***	-0.0140**
-8.19E-07	-0.0004	0.0051	-0.0150***	-0.005
6.79E-07	-0.0015	0.0029	-0.0157***	-0.0041
-7.23E-06	0.0076***	0.0118	-0.0242*	-0.0095
-2.62E-07	0.0001	-0.0011	-0.0165***	0.0008
8.01E-07	-0.0008	-0.0034*	-0.0098***	-0.0036*
-9.40E-07	-0.0001	-1.98E-05	-0.006	-0.0053
-1.09E-06	-0.0009	0.0023	-0.0125***	-0.0063
-5.41E-06	-0.0033**	0.0084	-0.0194***	-0.0092
-5.51E-07	-0.0012**	-0.0003	0.0016	0.0007
2.68E-06	0.0002	-0.0025	-0.0051*	0.0037
2.15E-07	-0.0023*	0.0014	-0.0019	-0.0031
-3.99E-06	0.0017	0.0116	-0.0202**	-0.0149*
-2.46E-06*	-0.0033***	0.0021	-0.0152***	0.0008
4.57E-06**	-0.0006	-0.0084***	0.0022	0.0087
-2.46E-07	-0.0007	0.0027	-0.0107***	-0.0027

Note: *Significant at the 0.10 level. **Significant at the 0.05 level. ***Significant at the 0.01 level.

Table 8. Estimated EGARCH models: Variance equation.

Stock returns	$\hat{\omega}$	$\hat{\alpha}$	$\hat{\gamma}$	$\hat{\lambda}$	Stock returns	$\hat{\omega}$	$\hat{\alpha}$	$\hat{\gamma}$	$\hat{\lambda}$
R2	-0.7955**	0.4643***	-0.0967	0.9583***	R13	-1.240**	0.5835***	0.0753	0.9223***
R3	-0.7097	0.4459***	0.1330*	0.9647***	R14	-0.98347*	0.4502***	0.0092	0.9358***
R4	-3.172**	0.1753*	-0.1876**	0.6979***	R15	-1.131***	0.3319***	-0.1122*	0.9103***
R5	-9.445***	1.039***	0.1747*	0.1456	R16	-9.059***	1.071***	-0.0490	0.2739*
R6	-2.088***	0.5855***	0.0176	0.8346***	R17	-1.293*	0.5595***	0.0013	0.9163***
R7	-8.959***	0.6915***	-0.0592	0.0732	R18	-9.536*	0.3331*	-0.1063	0.0572
R8	-0.9598	0.3692***	-0.0030	0.9312***	R19	-0.3412**	0.1279***	-0.159***	0.9746***
R9	-6.1174**	0.4195*	-0.1274	0.4221	R20	-8.183***	0.3801*	-0.3687**	0.1854
R10	-0.4269**	0.0681	-0.177***	0.9599***	R21	-1.131*	0.4297***	-0.0239	0.9215***
R11	-7.131***	0.4911**	-0.2156	0.3036	Rm	-0.9051*	0.4022***	0.0061	0.9409***
R12	-12.89***	1.471***	0.2657**	-0.164***					

Note: *Significant at the 0.10 level. **Significant at the 0.05 level. ***Significant at the 0.01 level.

Table 9. Estimated regression model for R1 considers as a dependent variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.017728	0.029224	0.606619	0.5448
CNCS	0.000001	0.000002	0.469621	0.6391
CD	-0.000894	0.001929	-0.463405	0.6436
VD	0.004409	0.005654	0.779877	0.4364
ND	-0.0000115	0.0000191	-0.602542	0.5475
HD	-0.001111	0.004355	-0.25521	0.7988
LD	-0.006438	0.008958	-0.718663	0.4732
GP	-0.066485	0.076716	-0.866639	0.3872
SP	0.001042	0.006964	0.149569	0.8813

6.2.1. Mean model reckoning

The reckoning of the mean equation for each return's series, specified in Table 7, discover that: First, the estimated coefficient $\hat{\beta}_1$ for daily new confirmed COVID-19 cases in Saudi (CNCS) is insignificant for the market index and all industry groups, except for Retailing and Transportation, which are negative significant at 5% and 10% statistical levels respectively. Whereas, for Food & Beverage is positive significant at 5% statistical level. Generally, it reveals that the Saudi Arabia market was insignificantly affected by the new developments of COVID-19 cases. Second, regarding the impact of the measures taken by the authorities in Saudi Arabia after the announcement of the first incidence in China (CD), the estimated coefficient $\hat{\beta}_2$ was insignificant for the main market index and all industry groups, except for Consumer Durables & Apparel, REITs, Utilities, and Transportation, which are negative significant at different statistical levels. Whereas, for Software & Services is positive significant at a 1% statistical level. Generally, it reveals that the Saudi Arabia market is insignificantly affected by the announcement of COVID-19 in China and the measures taken by Saudi authorities to prevent the outbreak of the pandemic at that time. Third, the estimated coefficient $\hat{\beta}_3$, which measure the impact of the COVID-19 period since the announcement of the first case in Saudi Arabia (VD) is insignificant for the main market index and all industry groups, except for, Diversified Financials, Commercial Srv, and Food & Beverage, which are negative significant at 5%, 10% and 1% statistical levels respectively. Whereas, for Retailing, Telecommunication Services and Media & Entertainment are positive significant at 5%, 10% and 5% statistical levels respectively. Generally, it shows that the Saudi Arabia market is insignificantly affected by the announcement of COVID-19 in Saudi Arabia.

Fourth, the nine trading days after the announcement of the first case in Saudi Arabia (*ND*) has a significant negative coefficient ($\hat{\beta}_4$) for the main market index and all industry groups, except for Pharma, Biotech & Life Science, Diversified Financials, Health Care Equipment & Svc, REITs, Utilities, and Food & Beverage, which are insignificant with different signs. It can be generalized that the Saudi Arabia market is negative significantly affected during these nine days. Fifth, regarding the impact of the measures taken by the authorities in Saudi Arabia the outbreak of COVID-19 in Saudi Arabia (*HD*) for the period from 16 to 25th March 2020, the estimated coefficient $\hat{\beta}_5$ is insignificant for the main market index and all industry groups, except for Retailing, Media & Entertainment, Commercial Srv, and Materials, which are negative significant at different statistical levels. Whereas, for Pharma, Biotech & Life Science is positive significant at a 1% statistical level. Generally, it reveals that the Saudi Arabia market is insignificantly affected by the measures taken by Saudi authorities to prevent the outbreak of the pandemic at that time.

Sixth, it is evident from Table 7 that the lock-down imposition (*LD*) has a significant impact on the Saudi stock market, as the estimated $\hat{\beta}_6$ coefficient is negative significant (5% and 10% statistical levels) for Retailing, Pharma, Biotech and life science, Consumer Durables & apparel, and Transportation industry groups. Whereas, the same estimated coefficient is positive significant (1% and 5% statistical levels) for Diversified financials and Food & Beverage industry groups. That is to say, different industry groups received different COVID-19 impact in terms of lock-down (*LD*), depending on their nature of business and contributions to the fight against COVID-19.

Seventh, the S&P 500 as the world's leading stock market indicator (*SP*), is found insignificant for the main market index and all industry groups except five industry groups. Whereas, the spot gold price (*GP*) is also found insignificant except for three industry groups in Saudi Arabia stock market. Generally, it reveals that the Saudi Arabia market is insignificantly affected by the change in the two control variables used in this study.

6.2.2. Variance equation fallouts

Based on Table 8 which presents the results of the variance equation for the EGARCH model, we observe that: the estimated coefficient of the EGARCH asymmetry term is negative and significant (at different statistical levels) for five industry groups in Saudi Arabia stock market, namely, Telecommunication Services, Software & Services, Consumer Durables & Apparel, Materials, and Transportation. This result indicates that there is a leverage effect in these five industry groups. It means that negative shock has a more significant impact on volatility than positive shocks of the same magnitude. For Real Estate Mgmt & Development, Pharma, Biotech & Life Science, and Commercial Srv, asymmetry term is positive and significant, implying that these three industry groups are more sensitive to the "good" news than to "bad" news.

The estimated coefficient of the persistence parameter $\hat{\lambda}$ is large for Saudi Arabia's main market index (0.9409) and fourteen industry groups, implying that the variance moves slowly through time. On the other hand, the opposite is exact for the remaining seven industry groups which the persistence estimated parameter $\hat{\lambda}$ is small. Regarding the estimated volatility clustering coefficient $\hat{\alpha}$, which is also called the symmetric effect, is significant for the main market index and all industry groups, except for Software & Services, which is found insignificant. Generally, this evaluation argues that although only 25% of the industry groups in Saudi stock market have leverage effect, shocks generated due to COVID-19 would persist for an extended period in these industry groups, as the estimated parameter $\hat{\lambda}$ is near to one for the majority of them.

7. CONCLUSIONS

The current study empirically attempts to estimate the effect of the COVID-19 related news on the stock market volatility by running the EGARCH model. The data set from 4th August 2019 to 21st May 2020 is considered derived from Saudi Arabia Stock Exchange Main Index, and its component industry groups indices are examined.

Six proxies represent COVID-19, namely, the daily new confirmed cases in Saudi (*CNCS*), the measures taken by the authorities in Saudi Arabia after the announcement of the first incidence in China (*CD*), the impact of the COVID-19 period since the announcement of the first case in Saudi Arabia (*VD*), the nine trading days after the announcement of the first case in Saudi Arabia (*ND*), the impact of the measures taken by the authorities to combat the outbreak of COVID-19 in Saudi Arabia (*HD*), and lock-down dummy (*LD*). Financial market variables, specifically the Standard and the Poor index (*SP*) and commodity markets represented by spot gold price (*GP*), are included for control purposes.

The findings of the mean equation calculations reveal that the Saudi Arabia market is neither significantly affected by the new developments of COVID-19 cases, nor affected considerably by the announcement of COVID-19 in China or Saudi Arabia. Moreover, the findings also indicate that different industry groups received different COVID-19 impact in terms of lock-down practiced there, depending on their nature of business and contributions to the fight against COVID-19. Noticeably, the Saudi Arabia market was significantly affected during the nine trading days after the first case in Saudi Arabia.

Regarding the variance equation analysis, the estimated EGARCH asymmetry term is negative and significant for only 25% of the industry groups in the Saudi Arabia stock market, namely, Telecommunication Services, Software & Services, Consumer Durables & Apparel, Materials, and Transportation. This result implies that there is a leverage effect in the mentioned five industry groups, which, in turn, means that negative shock has a more significant impact on volatility rather than the positive shock of the same magnitude. The estimated persistence parameter is large for Saudi Arabia's main market index (0.9409) and fourteen industry groups, implying that the variance moves slowly through time. Hence these sectors will recover after a long time upon removal of lock-down and when the pandemic is over.

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APPENDIX

Table A.1. Stock returns and its corresponding group

Stock returns	Group name	Stock returns	Group name
R1	Food & Staples Retailing	R13	Health Care Equipment & Svc
R2	Retailing	R14	Capital Goods
R3	Real Estate Mgmt & Development	R15	Consumer Durables & Apparel
R4	Telecommunication Services	R16	REITs
R5	Pharma, Biotech & Life Science	R17	Energy
R6	Diversified Financials	R18	Utilities
R7	Media & Entertainment	R19	Materials
R8	Banks	R20	Transportation
R9	Insurance	R21	Food & Beverage
R10	Software & Services	Rm	Main market (TASI)
R11	Consumer Services	SP	S&P 500 index
R12	Commercial_Srv		

Table A.2. Results of the unit root test at level

Variable	t-test	Prob.	variable	t-test	Prob.
R1	-11.7156	0.0000	R13	-12.9655	0.0000
R2	-14.0148	0.0000	R14	-12.8971	0.0000
R3	-11.3753	0.0000	R15	-15.1232	0.0000
R4	-13.7334	0.0000	R16	-14.4771	0.0000
R5	-12.7996	0.0000	R17	-11.9391	0.0000
R6	-14.4326	0.0000	R18	-15.2219	0.0000
R7	-15.9459	0.0000	R19	-13.5933	0.0000
R8	-13.1511	0.0000	R20	-4.2987	0.0000
R9	-13.8758	0.0000	R21	-13.5945	0.0000
R10	-13.3363	0.0000	Rm	-13.7169	0.0000
R11	-13.3240	0.0000	Gold	-3.5624	0.0357
R12	-12.8697	0.0000	SP	-18.9779	0.0000

Table A.3. Heteroscedasticity test for stock returns

Stock returns	F	Stock returns	F	Stock returns	F	Stock returns	F
R1	0.66	R7	54.50***	R13	23.70***	R19	47.18***
R2	31.47***	R8	37.62***	R14	44.51***	R20	25.65***
R3	45.20***	R9	27.22***	R15	50.43***	R21	71.53***
R4	47.60***	R10	23.44***	R16	54.36***	Rm	55.26***
R5	22.38***	R11	43.62***	R17	28.58***		
R6	29.62***	R12	48.63***	R18	2.83*		

Note: *Significant at the 0.10 level. **Significant at the 0.05 level. ***Significant at the 0.01 level.