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Consequences of COVID-19 on Banking Sector Index: Artificial Neural Network Model

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Abstract: The World Health Organization officially declared COVID-19 a global pandemic on 11 March 2020. In this study, we examine the effect of COVID-19 indicators and policy response on the Saudi banking index. COVID-19 variables that were applied are: new confirmed and fatal COVID-19 cases in Saudi Arabia; lockdowns; first and second decreases in interest rates; regulations, and oil prices. We implemented the analysis by running a stepwise regression analysis then building an artificial neural network (ANN) model. According to regression findings, oil prices and new confirmed cases have had a significant positive effect on the Saudi banking index. Nevertheless, the lockdown announcements in Saudi Arabia and the first decrease in interest rates had a significant negative effect on the Saudi banking index. To enhance the performance of the linear regression model, the ANN model was built. Findings showed that the ranking of the variables in terms of their importance is: oil price, number of confirmed cases, lockdown announcements, decrease in interest rates, and lastly, regulations.

Keywords: Saudi banking sector; COVID-19; ANN; decrease in interest rates; lockdown; regulations; confirmed cases; death cases

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1. Introduction

The world faced many challenges in 2020, starting with the new coronavirus (COVID-19) pandemic, moving to the oil price crash, and ending with new variants of the coronavirus. Since the declaration of COVID-19 as a global pandemic on 11 March 2020, followed by the announcement of worldwide lockdowns, all financial and non-financial sectors have been in shock. Lockdowns were the first response of governments and regulatory bodies to this pandemic. However, the lockdowns hurt all macroeconomic indicators (e.g., unemployment rates, inflation rates) and deteriorated the liquidity and stability of stock markets (Zhang et al. 2020; Baig et al. 2021). Nonetheless, different regulatory bodies applied many actions to mitigate the catastrophic effect of the COVID-19 pandemic. Incentive packages and credit facilities were provided by the governments of developed and emerging countries to offset some effects of the pandemic (Capelle-Blancard and Desroziers 2020; Topcu and Gulal 2020).

Accordingly, the effects of this pandemic became a key interest to many scholars. They have linked the COVID-19 pandemic to many financial and non-financial aspects. Several scholars investigated the effects of COVID-19 on financial market indices, primarily a significant negative effect (Zhang et al. 2020; Topcu and Gulal 2020; Li et al. 2020; Shehzad et al. 2020; Liu et al. 2020; Anh and Gan 2020; Erdem 2020). With regards to Akhtaruzzaman et al. (2021a) the authors investigated how financial contagion has occurred between China and G7 countries through financial and non-financial firms during the COVID-19 period. Their results showed that financial and non-financial firms have experienced a significant increase in conditional correlations between their stock returns. Moreover, the magnitude of the increase has been higher for financial firms during the COVID-19 outbreak. Moreover, in Akhtaruzzaman et al. (2021b) the authors examined the dynamic relationship between

the COVID-19 media coverage index (MCI) and ESG leader indices. On the one hand, their findings provide evidence that the MCI plays a role in facilitating the transmission of contagion to advanced and emerging equity markets during the pandemic. On the other hand, the COVID-19 outbreak has had a substantial effect on financial markets' volatility. Specifically, Harjoto et al. (2020) and Ali et al. (2020) showed that this pandemic has had a significant effect in increasing the volatility and risk of financial markets. Moreover, Baig et al. (2021) showed that COVID-19 indicators presented by increasing the number of confirmed cases and deaths are associated with a significant increase in US equity market volatility. In the same field, although Salisu et al. (2020a) found that emerging markets are more exposed to the risk of pandemics and epidemics (UPE), these markets show less hedging status compared with developed markets. In addition, the findings of Hevia and Neumeyer (2020) showed that the effect of the COVID-19 pandemic was worse in developing countries compared with developed countries, as developing countries have suffered from deteriorating exports and diminishing remittances within the pandemic period.

This pandemic affects stock market indices in general and specific sector indices in specific cases. One of the vital sector indices is the banking sector index, which has the highest volume. It is considered the main driver of the financial market index and has a strong effect on both the economy and financial markets. Only a few researchers have investigated the impact of COVID-19 on the banking sector and banking sector index, and they have found a severe effect of the pandemic on the banking sector (Singh and Bodla 2020; Wu and Olson 2020; Cakranegara 2020; Li et al. 2021). In Elnahass et al. (2021), the authors provided strong evidence that, in the global banking sector, the COVID-19 outbreak has had a detrimental effect on financial performance across many indicators of financial performance and financial stability. According to Demirgüç-Kunt et al. (2021), although financial sector policy announcements (i.e., liquidity support, monetary easing, and borrower assistance programs) moderated the negative impact of the pandemic, this impact has varied significantly across banks and countries. Besides, the findings of Demir and Danisman (2021) indicated that listed banks' returns, accompanied with better bank-specific factors (i.e., higher capitalization and deposits, more diversification, fewer non-performing loans, and larger size) have been more resilient to the COVID-19 pandemic.

Saudi Arabia is located at the heart of the Arab world. It is the world's largest oil exporter and second largest producer of oil in the world. The country is considered a World Bank high-income economy and is a member of the Gulf Corporation Council, OPEC, and the only Arab member of the G20. According to Saudi Vision 2030, the kingdom is deploying its strategic location to build its role as an integral driver of international trade and to connect three continents: Africa, Asia, and Europe. In addition, Saudi Arabia is using its investment power to create a diverse and sustainable economy. Even though the Saudi economy is the largest in the Middle East and the ninth largest in the world, it has experienced negative consequences due to COVID-19, the subsequent lockdowns, and the later oil prices crash. The consequences of COVID-19 for the Saudi economy worsened most of the macroeconomic indicators in 2020; GDP growth decreased to −3.7%, the budget deficit reached approximately SAR 298 billion, public debt rose to SAR 854 billion, the TASI hit the bottom at −29.7%, and the unemployment rate increased to 15.4%. As a consequence, the Fitch and Moody's credit rating agencies downgraded the outlook of the Saudi economy.

Moreover, the Saudi economy and banking sector have been facing a difficult period as the economy faces a dual threat from COVID-19 and oil prices. The pandemic has caused substantial deterioration in Saudi banks' asset quality, heavy losses in savings accounts, and increased demand for credit with no genuine tendency to save. Therefore, Saudi banking aggregate income decreased by 28% in September 2020 as income fell from SAR 34.77 billion in September 2019 to SAR 25.07 billion in the same period of 2020. Although the Saudi government intervened in the early stages of COVID-19, the Saudi stock market index and banking sector index faced serious challenges and obstacles in mitigating the

severe outcomes of the pandemic. Few researchers have investigated the effect of this pandemic on the Saudi financial market index, and even fewer have examined the Saudi banking sector (Chaouachi and Slim 2020; Al-Tamimi and Abdalla 2021).

Many researchers studied the effect of the pandemic on different equity markets' indices. However, Zhang et al. (2020), Baig et al. (2021), Akhtaruzzaman et al. (2020), and Akhtaruzzaman et al. (2021a) concentrated on the damage that was accompanied by their financial markets in developed and emerging countries. Few researchers focused on the effect of this pandemic on either developing markets or on Saudi Arabia's financial market. Besides, researchers were interested in studying the effect of COVID-19 on the whole index with no specification for special sectors. Few academics studied the effect on specific sectors, such as the banking sector index (Elnahass et al. 2021; Demirgüç-Kunt et al. 2021; Demir and Danisman 2021). In investigating the effect of this pandemic on equity markets, most researchers applied different models of regression analysis. However, researchers rarely used advanced prediction and intelligent models to specify the ability to build robust prediction systems that can be used in any similar circumstances in the future. Moreover, the importance of these prediction models appears strongly dependent on their ability to specify the best parameters for future prediction. Furthermore, the COVID-19 indicators that were implemented by scholars differ from one study to another. Some researchers focused on the number of confirmed cases and death cases, whereas a few examined the effect of government regulations and decreasing interest rate. Even fewer researchers link the effect of oil crash on different equity markets.

Our study makes the following contributions to the previous literature. First, our study focuses on examining the effect of different COVID-19 indicators, COVID-19 policy response, and oil prices on the Saudi banking index. Second, the COVID-19 indicators include the number of confirmed and number of death cases in Saudi Arabia. COVID-19 policy response includes lockdowns, decreasing the rates of repo and reverse repo, and new government regulations in the Saudi market through the pandemic. Third, we use regression analysis and an artificial neural network (ANN) model to build a prediction model for the Saudi banking index and to determine the most important factors for predicting the banking index. Fourth, we highlight the most important relative literature that studied the effect of the pandemic on different equity markets.

In this study, we implemented our methodology by running stepwise regression and ANN models. According to the regression findings, oil prices and new confirmed cases have had a significant positive effect on the Saudi banking index. However, the lockdown announcement and the first decrease in interest rate have had a significant negative effect on the Saudi banking index. To enhance the performance of the linear regression model, the ANN model was built. The findings showed that the rank of the variables according to their importance is oil price, number of confirmed cases, the lockdown, decrease in interest rate, and regulations.

This study has seven sections. Section 2 presents the literature review. Section 3 describes the data. Section 4 explains the methodology. Section 5 discusses the conclusions, and Section 6 provides the practical implications. Lastly, Section 7 discusses the limitations and possible avenues for further study.

2. Literature Review

2.1. Highlights on COVID-19

The financial market index is one of the essential macroeconomic indicators that play a vital role in economies. The collaboration between economic and non-economic factors leads to a strong fluctuation in the stock market index (Assous et al. 2020). Consequently, the estimation of the stock market index is a complicated task due to linear and non-linear factors (Assous et al. 2020; Gurjar et al. 2018).

Most stock markets' indices have had quick and negative reactions to the COVID-19 pandemic. Zhang et al. (2020) investigated the pattern of country-specific risk, systematic risk, and new government regulations in global financial markets during the pandemic

period. They found that the pandemic had a strong effect on global markets and that new government regulations may create further uncertainties in the global financial market. Moreover, Khan et al. (2020) explored the effect of the pandemic on 16 countries, and their results showed that investors did not react in the early stages of the pandemic, but all stock market indices were negatively affected by the COVID-19 outbreak later. Finally, Shehzad et al. (2020) revealed a significant negative association between COVID-19 and S&P 500 returns. According to Zhang et al. (2020) and Capelle-Blancard and Desroziers (2020) who investigated different financial markets, oil, and gold markets, a deteriorating situation is expected in the markets as the pandemic continues. Liu et al. (2020) also estimated the short-run effect of the COVID-19 pandemic on financial markets by applying the event study approach and showed that COVID-19 has an inverse effect on equities returns.

As stated by Liu et al. (2020) and AlAli (2020), Asian countries and major Asian stock markets experienced a negative abnormal return due to the pandemic. Additionally, Topcu and Gulal (2020) proved that Asian markets not only have negative returns, but the highest negative COVID-19 impact compared with European countries. In a specific analysis on COVID-19 confirmed and death cases, Liu et al. (2020) and Anh and Gan (2020) exhibited an adverse impact of confirmed cases on stock markets indices. Moreover, Erdem (2020) showed that the number of confirmed cases had a significant negative effect on global financial markets' return, and this negative effect is less prominent in more democratic countries than in less-democratic countries. In addition, Ashraf (2020) examined stock markets' response to the pandemic outbreak and found that stock markets responded negatively to the growth of confirmed cases, especially in the early stages of the pandemic. Nevertheless, Capelle-Blancard and Desroziers (2020) found that investors are sensitive to confirmed cases in neighboring wealthy countries. Additionally, Alber and Arafa (2020) found that stock market return in the MENA region was negatively affected by new and cumulative death cases. Besides, Ashraf (2020) revealed that stock markets reacted faster to increasing confirmed cases than to increasing death cases. Harjoto et al. (2020) found that confirmed and death cases in emerging markets have had a negative effect on the stock market return and a positive effect on market volatility, and developed markets are only affected by confirmed cases with no effect for death cases on their stock market return.

Despite the current negative consequences of COVID-19, scholars found that most of the stock markets overreacted during the early stages of the pandemic. As more information becomes available and people understand the complications broadly, the recovery of stock markets from negative COVID-19 impact is highly expected (Singh et al. 2020; Sha and Sharma 2020). As an example, Khan et al. (2020) found that the Shanghai Stock Market has regained the confidence of investors after the harmful period of the pandemic. Besides, Topcu and Gulal (2020) showed that the negative impact on Asian markets has fallen gradually and began to diminish.

2.2. COVID-19 and the Saudi Banking Sector

In April 2020, the whole world woke up to a decrease in oil prices of more than 20% in one day, which started a new phase of twin pandemics (i.e., COVID-19 and the oil price crash). These two crises have a dual effect on increasing the distress and instability in the economies in general and specifically in stock markets (Salisu et al. 2020a; Albulescu 2020; Lyócsa et al. 2020). In facing the COVID-19 outbreak and oil prices crash, the Saudi Central Bank (SAMA) imposed many regulations and applied many tools to minimize the effect of the pandemic. These new regulations and tools have been positively received and directly reflected in the economy and have had a strong effect in mitigating the effects of the COVID-19 pandemic. SAMA increased borrowings and deposited huge amounts in the banking sector in 2020 to enhance banking liquidity, to continue providing credit facilities for private sectors, and to protect all sectors such as SMEs' credit deferrals. Only a few researchers have studied the impact of COVID-19 on the Saudi stock market index (TASI). Chaouachi and Slim (2020) found an inverse impact of the pandemic on TASI, and a test

of causality reveals unidirectional type from COVID-19 frequency's measure to the stock market. In addition, Al-Tamimi and Abdalla (2021) revealed a positive effect of oil price on the economic growth of Saudi.

Banks are important financial institutions, and both conventional and Islamic banks play a major role in the economy (Musa et al. 2021; Musa et al. 2020). However, only a few researchers investigated the impact of the COVID-19 pandemic on the banking sector and the banking sector index. For example, Singh and Bodla (2020) found a severe effect of the pandemic on the banking sector. Wu and Olson (2020) showed that the impact of the pandemic on the banking sector consists of long-term, short-term, and systematic risk. Cakranegara (2020) found that Indonesian banking is resilient to crises and that government decisions regarding macroeconomic strategies and credit terms are needed to maintain economic stability (Wu and Olson 2020; Li et al. 2021). Bernardelli et al. (2021) also proved that large retail banks were less affected by COVID-19 compared to medium-sized banks with rich corporate portfolios. According to Elnahass et al. (2021), Demirgüç-Kunt et al. (2021), and Demir and Danisman (2021), the pandemic proved to have a negative impact on all financial sectors and banks. Thus, the sharpness of this negative effect differs from one country/bank to another. Accordingly, countries with high financial stability and better financial policy or banks with better KPIs will encompass less harmful COVID-19 consequences.

3. Data

3.1. Data Description

To study the impact of COVID-19 indicators and COVID-19 policy response on the Saudi banking index, we took the following variables into consideration: COVID-19 indicators measured by the number of COVID-19 confirmed cases and the number of COVID-19 death cases. COVID-19 policy response was measured by lockdown announcement, regulations of SAMA, decrease in the interest rate of repo and reverse repo, and oil prices. The data were collected from the Johns Hopkins, Tadawul, WHO, and SAMA websites, for the period from 1 January 2020 to 3 December 2020.

Starting with the lockdown, which is the most powerful impact of COVID-19 on economies worldwide, the Saudi government officially imposed a lockdown on 9 March 2020 with specific restrictions and predetermined curfew times in all Saudi cities. Travel between cities and districts was restricted, all international flights were cancelled, and most businesses were closed (i.e., retail shops, malls, salons, and so forth). All places where social distancing cannot be applied were closed (i.e., football stadiums, fun cities, festivals, and so forth). The lockdown is a key variable used by many researchers to study its effect on the financial market (Zhang et al. 2020; Baig et al. 2021). In our paper, we use the lockdown announcement date as an independent variable to study its effect on the Saudi banking sector index.

As the first lockdown was imposed, the Saudi government and SAMA used different monetary and fiscal tools to mitigate the consequences of COVID-19 on the Saudi economy in general and on banks specifically. The set of regulations that were implemented by SAMA consists of increasing the external borrowings by SAR100 billion and injecting SAR 214 billion to support private businesses as SMEs credit payment deferrals, wages for private-sector workers, and exemptions from the costs of a loan guarantee program. Government regulations were used by many researchers to study their effect on the financial market (Capelle-Blancard and Desroziers 2020; Topcu and Gulal 2020). In our paper, we use government regulations date as an independent variable to study their effect on the Saudi banking sector index.

Furthermore, SAMA decreased the interest rate of repo and reverse repo twice in March 2020 with a total decrease of 125 basis points. This action is commonly used by central banks to encourage spending and maintain a stable economy and was first adopted by the US Federal Reserve. Cutting these rates is a benchmark of banking credit repricing, which aimed to decrease the borrowing cost for the benefit of debtors, especially SMEs. This

action was taken to help these businesses and consequently secure the employment rate. Other sub-benefits of interest cuts are related to mortgages and personal and auto loans, which became cheaper and probably secured to be repaid. Other researchers studied the effects of decreasing interest rates on the financial market (Capelle-Blancard and Desroziers 2020). In this paper, we investigated the effect of the first and second decrease in interest rates on the Saudi banking sector index.

According to the Saudi Ministry of Health, the first confirmed COVID-19 case was recorded on 2 March 2020, and the first death was announced on 22 March 2020. Many researchers used the number of COVID-19 confirmed cases and COVID-19 death cases (Ashraf 2020; Harjoto et al. 2020; Liu et al. 2020; Alber and Arafa 2020). In our study, we use the number of confirmed COVID-19 cases and COVID-19 deaths as independent variables to study their effect on the Saudi banking sector index.

Additionally, Saudi Arabia, as a member of G20 countries with one-quarter of world oil reserves, depends heavily on oil revenues compared with non-oil revenues. The Saudi economy was strongly impacted by oil prices' deterioration, which started in April 2020 as a consequence of the COVID-19 pandemic. Sharif et al. (2020) used oil price to study its effect on the US economy. In this paper, we use oil price as one of the independent variables to study its impact on the banking sector index.

3.2. Data Analysis

In this section, we discuss the descriptive statistics and the correlation matrix of our variables. Table 1 shows 231 observations for the period from 1 January to 3 December 2020. The maximum COVID-19 confirmed cases was 4,919 cases on 17 June 2020. However, in the same period, the maximum number of death cases was 58 cases on 5 July 2020. Oil prices within the study period vary between a minimum of USD 10/barrel and a maximum of USD 65/barrel. The banking sector index has a maximum of 8194 points on 16 January 2020, whereas it hit the bottom on 16 March with 5382 points.

Table 1. Descriptive statistics of the variables.

	N	Maximum	Mean	Std. Deviation
Daily Cases	231	4919	1022.801	1209.518
Daily Deaths	231	58	17.294	15.556
Oil	230	65	31.307	15.269
Banking Index	231	8194	6860.324	694.868
Valid N (listwise)	230			

In the correlation matrix presented in Table 2, all independent variables except for oil price have a significant negative relation with the Saudi banking sector. The lockdown had the strongest negative relationship with the banking index, whereas oil price has a significant positive relation with the Saudi banking index.

Table 2. Correlation matrix of the variables.

		Banking Index	Regulation	First Decrease Rate	Second Decrease Rate	Lockdown	Daily Cases	Daily Deaths
Banking index	Corr	1						
	Sig.							
Regulation	Corr	−0.463 **	1					
	Sig.	0.000						
FirstDecRate	Corr	−0.172 **	−0.372 **	1				
	Sig.	0.009	0.000					
SecondDecRate	Corr	−0.527	0.965	−0.385	1			
	Sig.	0.000	0.000	0.000				

Table 2. *Cont.*

		Banking Index	Regulation	First Decrease Rate	Second Decrease Rate	Lockdown	Daily Cases	Daily Deaths
Lockdown	Corr	−0.774 **	0.222 **	0.116	0.269	1		
	Sig.	0.000	0.001	0.079	0.000			
Daily_Cases	Corr	−0.440 **	0.484 **	−0.180 **	0.468	0.396 **	1	
	Sig.	0.000	0.000	0.006	0.000	0.000		
Daily_Deaths	Corr	−0.173 **	0.638 **	−0.237 **	0.615	−0.089	0.733 **	1
	Sig.	0.009	0.000	0.000	0.000	0.178	0.000	
Oil	Corr	0.862 **	−0.673 **	0.070	−0.698	−0.681 **	−0.701 **	−0.464 **

** Significance at 0.05.

4. Methodology

To answer our research questions, we implement our methodology in two steps. First by running a regression model, and second by building an ANN model.

4.1. Regression Model

To study the impact of COVID-19 indicators, COVID-19 policy response, and oil price on the Saudi banking index, a regression model was built. We started by checking the regression assumptions by applying the tests of linearity, normality, multicollinearity, hetreoscadististy, and autocorrelation. Accordingly, both government regulations and the second decrease rate are excluded from the regression model.

By using a stepwise regression model, we ran six regression models as shown in Tables 3 and 4. The best model was the model with the highest adjusted R-squared and lowest standard error. Accordingly, model number 6 was the best model with an adjusted R-squared of 86.9% and a standard error of around 250.7.

Table 5 shows that the lockdown announcement has a significant negative effect on the Saudi banking index. The effect is strongly expected as all economic activities and actions were suddenly stopped worldwide. The lockdown announcement sent a strong shock to all economic sectors in general and the banking sector in specific. On the one hand, borrowers cannot pay back loans. On the other hand, depositors are not willing to save anymore. Many other researchers found this negative effect (Zhang et al. 2020; Baig et al. 2021; Al-Najjar et al. 2021).

Table 3. Summary of models using stepwise linear regression.

Model	R	R^2	Adjusted R^2	Error
1	0.862 [a]	0.744	0.743	351
2	0.902 [b]	0.814	0.812	300
3	0.919 [c]	0.844	0.842	275
4	0.924 [d]	0.854	0.851	267
5	0.933 [e]	0.871	0.868	251
6	0.933 [f]	0.871	0.869	251

a. Predictors: (Constant), Oil
b. Predictors: (Constant), Oil, Daily_Deaths
c. Predictors: (Constant), Oil, Daily_Deaths, FirstDecRate
d. Predictors: (Constant), Oil, Daily_Deaths, FirstDecRate, Lockdown
e. Predictors: (Constant), Oil, Daily_Deaths, FirstDecRate, Lockdown, Daily_Cases
f. Predictors: (Constant), Oil, FirstDecRate, Lockdown, Daily_Cases
Dependent Variable: Suadi Banking Index

Table 4. ANOVA test of the linear regression model using Saudi Banking Index as the dependent variable.

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	81,545,027	1	81,545,027	662	0.000
	Residual	28,087,928	228	123,193		
	Total	109,632,955	229			
2	Regression	89,213,123	2	44,606,561	496	0.000
	Residual	20,419,832	227	89,955		
	Total	109,632,955	229			
3	Regression	92,557,955	3	30,852,652	408	0.000
	Residual	17,075,000	226	75,553		
	Total	109,632,955	229			
4	Regression	93,622,040	4	23,405,510	329	0.000
	Residual	16,010,916	225	71,160		
	Total	109,632,955	229			
5	Regression	95,507,619	5	19,101,524	303	0.000
	Residual	14,125,336	224	63,060		
	Total	109,632,955	229			
6	Regression	95,487,855	4	23,871,964	380	0.000
	Residual	14,145,100	225	62,867		
	Total	109,632,955	229			

Table 5. Coefficients of the linear regression model, with banking index as a dependent variable.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Tolerance	VIF
		B	Std. Error	Beta				
1	(Constant)	5631.664	52.887		106.484	0.000		
	Oil	39.080	1.519	0.862	25.728	0.000	1.000	1.000
2	(Constant)	5204.466	64.679		80.467	0.000		
	Oil	45.355	1.465	1.001	30.956	0.000	0.785	1.274
	Daily_Deaths	13.285	1.439	0.299	9.233	0.000	0.785	1.274
3	(Constant)	5280.975	60.380		87.462	0.000		
	Oil	44.927	1.344	0.991	33.421	0.000	0.783	1.277
	Daily_Deaths	11.177	1.356	0.251	8.242	0.000	0.742	1.348
	FirstDecRate	−609.643	91.625	−0.180	−6.654	0.000	0.941	1.063
4	(Constant)	5661.025	114.424		49.474	0.000		
	Oil	37.684	2.283	0.832	16.508	0.000	0.256	3.910
	Daily_Deaths	7.267	1.660	0.163	4.379	0.000	0.467	2.143
	FirstDecRate	−575.168	89.367	−0.170	−6.436	0.000	0.932	1.074
	Lockdown	−252.884	65.396	−0.174	−3.867	0.000	0.321	3.117
5	(Constant)	5671.773	107.733		52.647	0.000		
	Oil	38.733	2.157	0.855	17.953	0.000	0.254	3.941
	Daily_Deaths	−1.234	2.204	−0.028	−0.560	0.576	0.234	4.265
	FirstDecRate	−529.526	84.540	−0.156	−6.264	0.000	0.922	1.084
	Lockdown	−410.719	67.992	−0.282	−6.041	0.000	0.263	3.802
	Daily_Cases	0.152	0.028	0.266	5.468	0.000	0.243	4.117
6	(Constant)	5636.004	86.610		65.073	0.000		
	Oil	39.262	1.937	0.866	20.273	0.000	0.314	3.185
	FirstDecRate	−528.698	84.398	−0.156	−6.264	0.000	0.923	1.084
	Lockdown	−384.439	49.111	−0.264	−7.828	0.000	0.503	1.990
	Daily_Cases	0.141	0.020	0.247	7.168	0.000	0.483	2.069

Oil prices in Saudi Arabia and the rest of the world began to deteriorate in April 2020, leading the whole world to a new phase of the twin pandemic era (i.e., COVID-19 and the oil crash). Moreover, the lockdowns and suspension of transportation led to a decrease in oil demand and pushed prices to further deterioration (Sharif et al. 2020). The Saudi economy, as an oil-based economy, depends heavily on oil price, and oil revenue is considered the main source of income. According to our analysis, oil prices have a positive

significant impact on the Saudi banking index. Thus, the Saudi banking index is affected by COVID-19 but in an indirect way through the effect of this pandemic on oil prices. Our finding of the significant positive effect of oil price is in line with that of Salisu et al. (2020b) and Sharif et al. (2020).

Decreasing rates of repo and reverse repo first implemented by US federal reserves were adopted by SAMA to mitigate the outcomes of the COVID-19 outbreak. SAMA decreased both rates twice in 2020 with a total of 125 basis points to increase the money supply and enhance economic growth. Our findings showed a significant negative effect of the first decrease in interest rate on the Saudi banking index. Interest rate cuts will lead to a narrow net interest margin, slow credit growth, and higher bad loans and provisions. All these factors are also expected to negatively affect banks' profits and banking index. This result is contrary to the finding of Capelle-Blancard and Desroziers (2020) and Narayan et al. (2021), who found that this decrease affects the whole economy positively.

In Table 5, the number of new confirmed and death cases are tested; the results explored that new death cases have no significant effect on the banking index. However, the number of new confirmed cases showed a significantly positive effect on the Saudi banking index. Accordingly, the result is consistent with the findings of Harjoto et al. (2020) and Ashraf (2020), who found that markets are only affected by confirmed cases with no effect/minimal effect for death cases on stock market return. The finding contrasts with that of Liu et al. (2020) and Anh and Gan (2020) who found an adverse impact of confirmed cases on stock market indices, and Harjoto et al. (2020) showed that confirmed cases and deaths have a negative effect on stock market return in emerging markets. Besides, Alber and Arafa (2020) found that stock market return in the MENA region is negatively affected by new and cumulative death cases.

To sum up, COVID-19 and its consequences (i.e., lockdown, decrease interest rate, number of daily confirmed cases, and oil prices) have had a strong effect on the Saudi banking index and Saudi economy. The results showed an inverse effect of COVID-19 indicators and policy response on the Saudi banking sector, which is in line with the literature (Zhang et al. 2020; Shehzad et al. 2020; Erdem 2020; Khan et al. 2020; Ashraf 2020; Narayan et al. 2021).

4.2. ANN Model

Although the ANN model is a relatively new technique in economics, many scholars have proven that ANN is one of the best models to investigate economic problems and can be used to study financial indicators and to explore the impact of COVID-19 financial markets' indices (AL-Rousan et al. 2020; Al-Najjar and Al-Rousan 2020). Moreover, Tabar et al. (2020) showed that algorithms can predict stock market collapse in advance. Mollalo et al. (2020) applied a MLP/neural network to estimate COVID-19 frequency rates in the US to propose useful insights regarding risk indicators that accompany the COVID-19 pandemic. Furthermore, Tamang et al. (2020) showed that ANN can be used to estimate future cases of COVID-19 in different countries.

According to our regression model in the previous section, the performance of this model is less than 88%, and it depends only on four variables. Thus, to make these results more realistic and reflect real-life situations for the Saudi banking index without causing a multicollinearity problem, the neural network model was built. Linear regression also assumes that the input of the regression model is independent, which makes it difficult to use in the complex stock market index. Therefore, the authors shifted to a neural network non-linear regression model to improve the performance of the model and to create a complex relationship between input variables and the dependent variable. Consequently, this neural network model will apply more independent variables with no multicollinearity among independent variables and will rank the independent variables according to their importance in this model. As shown in Figure 1, a neural network model was built to improve the performance of linear regression and to enhance the investigation of the effect of COVID-19 indicators and policy response on the Saudi banking index.

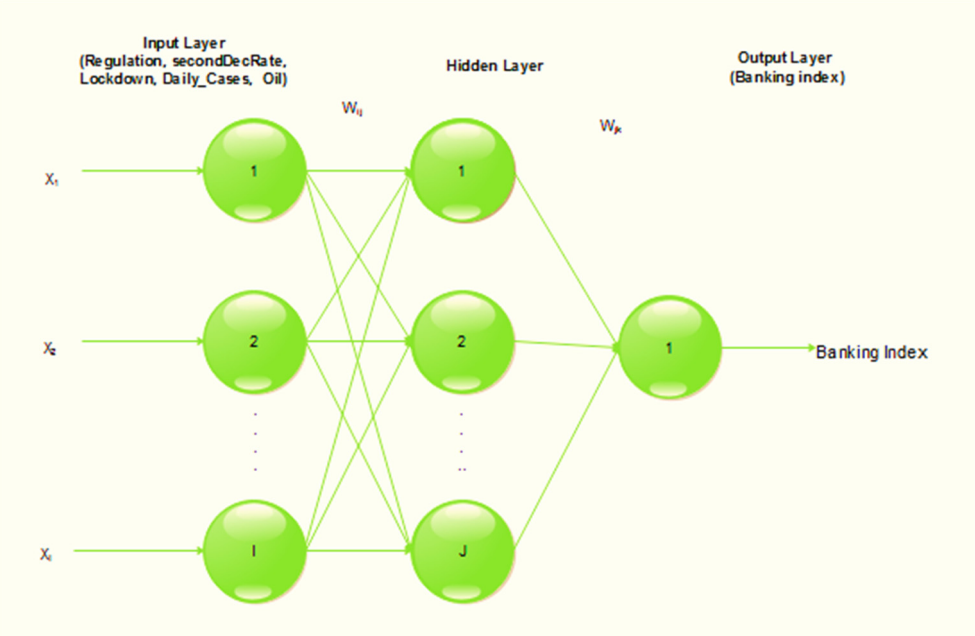

Figure 1. Neural network architecture of banking index prediction using one hidden layer.

The prediction output of the banking index is calculated as follows.

$$\text{Banking Index} = f\left(\sum_{j=1}^{2} O_j \, w_j + b_1\right) \tag{1}$$

where banking index is the output of the output layer, $f(.)$ is the transfer function, w_{jk} is the weight from the jth node in the hidden layer to the kth hidden node in the output layer (in our study, k equals 1), and b_1 is the bias of the output node. The performance and accuracy of a neural network depend mainly on determining the most accurate values of weights and biases aside from the number of hidden layers and the transfer function in each node. Therefore, various tests are used to find out the most suitable parameters that can achieve high performance. Moreover, the time complexity of the developed model is calculated after defining the number of hidden layers (h), number of output (c), number of inputs (d), and Big O notation (O). Therefore, the time complexity of the neural network is calculated as follows:

$$\text{Time complexity } = O(d \times h) + O(h \times c) = O(d \times h) + O(h \times 1) \tag{2}$$

To achieve the best performance of the neural network, the parameters of the neural network model are tuned by using mean square error and R^2 as performance metrics as shown in Table 6.

As seen in Table 7, the ANN model has maximized both R^2 and root mean square error (RMSE) with 96% and 194, respectively.

Table 6. Performance metric of neural network.

Parameter	Value
Number of Epochs	1000
Mu	1×10^{10}
Gradient Descent	1×10^{-7}
Performance	1×10^{-15}
Total number of parameters	5
Training ratio	70%
Testing ratio	30%
Number of neurons	10
Hidden transfer function	Tansig
Output transfer function	Purlin
Optimization Algorithm	Levenberg–Marquart (LM)

Table 7. Overall neural network metrics of the developed model, with banking index as a dependent variable.

Metric	Value
R^2	0.96
MAE	168
MSE	37,748
RMSE	194

Figures 2 and 3 show that the relationship between predicted and real values are linear, which indicates that the predicted values are near the real values. Besides, the residual error proves that the predictor can predict the Saudi banking index accurately.

ANN has become a well-formed estimator in many research fields (Novak et al. 2021). It has been used to solve many business problems, thus leading several academics to use ANN to estimate market return for macroeconomic factors' forecasts and international stock indices (AL-Rousan et al. 2020; Tabar et al. 2020; Tamang et al. 2020). Wilson and Bettis-Outland (2020) showed that ANN models can give predictions that are the same or even more accurate than the logistic regression model.

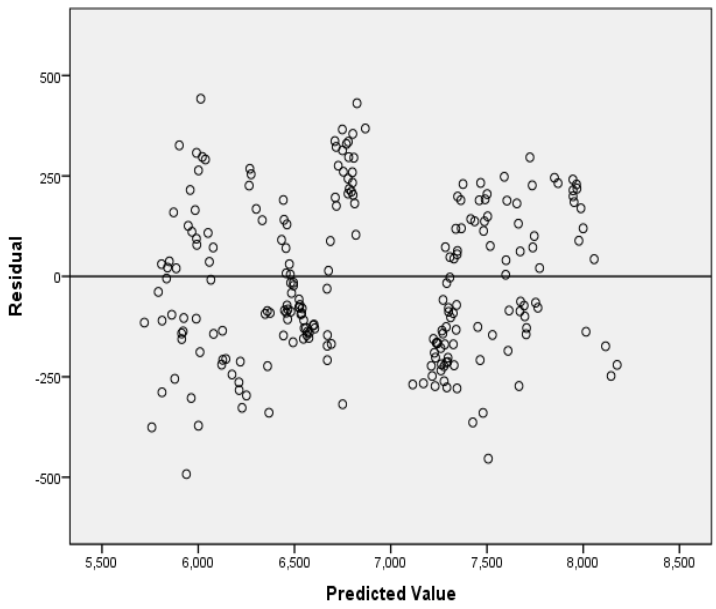

Figure 2. Residual differences between real and predicted banking index variables using a developed neural network model.

Figure 3. Relationship between banking index and prediction value using developed neural network.

Among the best practices in ANN is normalizing the data and specifying the relative importance of each factor in the model. As presented in Figure 4, the ANN model showed the relative importance of each variable so that we can rank variables depending on the importance factor. Accordingly, oil price is the most important variable among all variables in verifying the impact of the COVID-19 pandemic on the Saudi banking index, yet this effect is indirect. Thus, the Saudi banking index is affected by COVID-19 indicators and policy response through oil price as an intermediary variable. This result is consistent with the findings of Sharif et al. (2020), who showed that oil crashes have the strongest impact on the US stock market.

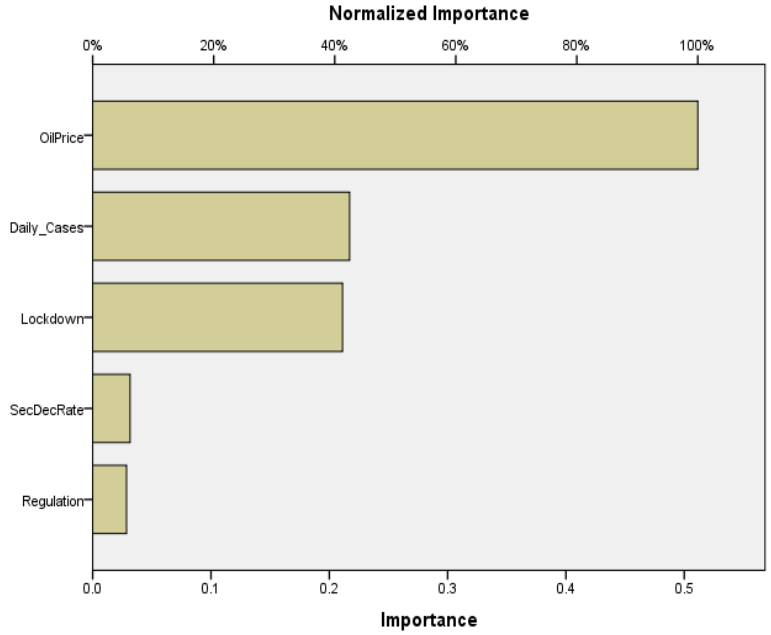

Figure 4. Important variables according to the neural network model.

New confirmed cases and lockdown indicators rank second and third, respectively, in the level of importance of investigating the effect of COVID-19 on the Saudi banking index. This result is consistent with previous findings (Zhang et al. 2020; Baig et al. 2021; Al-Najjar et al. 2021).

Lastly, the second decrease in interest rate and regulations has the least impact on the Saudi banking sector index due to ANN model outcomes. Regulations are important as these regulations assisted retailers, wholesalers, and the whole economy in facing COVID-19. This result is in line with the findings of Capelle-Blancard and Desroziers (2020), Topcu and Gulal (2020), and Narayan et al. (2021), who found that government incentive packages and wise decisions have an efficient effect on mitigating COVID-19 consequences on developing and developed economies.

Nevertheless, the ANN model revealed that the first decreases in interest rate and death cases are not important variables in predicting the Saudi banking index. This finding indicates that the number of death cases cannot be considered one of the important factors in predicting the Saudi banking index. This result is consistent with the findings of Harjoto et al. (2020) and Ashraf (2020).

5. Conclusions

Our study aimed at studying the effect of COVID-19 indicators and policy response on the Saudi banks index for the period from 1 January 2020 until 3 December 2020. COVID-19 indicators were measured by the number of COVID-19 confirmed cases and the number of COVID-19 death cases. COVID-19 policy response was measured by the lockdown announcement, SAMA regulations, decrease in the interest rate of repo and reverse repo, and oil prices. The analysis was conducted by calculating the correlation matrix between variables, running stepwise regression analysis, then building an ANN model. Our results showed that the regression model of the Saudi banking index is significant with an adjusted R^2 of 86.9% and standard error of around 250.7.

According to the regression analysis findings, oil prices and new confirmed cases had a significant positive effect on the Saudi banking index. Nevertheless, the lockdown announcement in Saudi Arabia and first decrease in the interest rate for repo and reverse repo had a significant negative effect on the Saudi banking index.

To enhance the performance of the linear regression model, an ANN model was built with R^2 and RMSE of 96% and 194, respectively. The findings of ANN normalized importance showed that oil price is the most important variable that affects the Saudi banking index. This result is in line with Saudi Arabia's economy being one of the greatest oil-based economies, with around one-quarter of world oil reserves.

The number of confirmed cases and lockdown announcement rank second and third, respectively, in importance on the Saudi banking index. These two indicators are the major direct consequences of COVID-19 that affect not only the Saudi banking index but economies worldwide. The second decrease in interest rate and regulations rank fourth and fifth. They are the corrective actions (i.e., monetary and fiscal policy tools) that were adopted by SAMA to minimize the impact of COVID-19 consequences on the Saudi economy and banking sector. Our results are consistent with related literature reviews of COVID-19 and its outcomes.

6. Practical and Theoretical Implications

Our research is theoretically and practically important. Our findings are important for stockholders and managers to understand the nature of stock markets, because these markets respond directly and randomly to any shocks in the economy, such as the COVID-19 pandemic. Investors should consider equity choices that are less risky than stock as an alternative investment and derivatives.

According to our result, the Saudi banking index depends heavily on oil price; hence, the Saudi government should take serious actions to minimize such dependence. Policy-makers can benefit from our findings by building an early warning system and applying special strategies to predict possible future crises. Moreover, policymakers should enhance procedures that can increase investors' confidence in the financial markets through minimizing media bias, given the increasing market volatility, investors' random selection, or

herding because of news (Baek et al. 2020). Policymakers must assure that only correct and honest information is published and traded.

Banks rely heavily on the government's support to regain customers' trust and to rebuild the resilience of the banking sector. Accordingly, government support for sectors and individuals should be maintained and enhanced until they return to the pre-pandemic level. In addition, fintech in Saudi Arabia played a vital role in all sectors and proved its ability in facing different economic challenges. Therefore, fintech and R&D should always be in continuous improvement.

Finally, as one of the worst pandemics in this century, COVID-19 took a toll on the global economy and caused severe consequences in all aspects. Most importantly, the pandemic will never be diminished without increasing people's awareness of this virus, implementing precautionary procedures, and having sufficient vaccine doses.

7. Limitations and Future Studies

Future studies may explore the effect of COVID-19 indicators on other GCC banking indices by using ANN. Future research can use more macroeconomic and banking-specific variables to build an early warning system for the Saudi banking sector. In addition, further research may apply more specific neural network models (i.e., long-short term memory and one attention-based neural network) to study the effect of this pandemic on different sectors' indices (i.e., insurance companies index, real estate index).

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