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Modelling the Impact of World Oil Prices and the Mining and Quarrying Sector on the United Arab Emirates' GDP

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Abstract: In this research, we aimed to model the impact of world oil prices on the gross domestic product of the United Arab Emirates (UAE). The objective of the study was to determine the transmission mechanism of the influence of the changing oil price within the macroeconomic indicators of the UAE. In this study, we analysed the impact of world oil prices and the crude oil sector on economic growth in the UAE for the period of 2001–2020 by applying ADF, OLS, ARDL, and Granger causality techniques. The results also showed the direct impact of the changes in oil prices on the GDP of the UAE in the short and long terms; in other words, a decline in oil prices could pose a threat to the economic security of the UAE in the long term if appropriate corrective measures are not taken. In order to avoid these negative consequences of the oil price crisis, in this study, we emphasize that the only alternative to exporting oil is to diversify economic sources for long-term development and increase the efficiency of non-oil sectors.

Keywords: macroeconomic modelling; United Arab Emirates; crude oil prices; world energy markets; economic development; emerging markets; non-oil revenue; economic diversification

MSC: 58E17; 91B72; 91B84

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1. Introduction

The UAE is the third largest economy in the Middle East [1]. It is an important producer of natural gas and oil, ranking seventh globally in terms of total proven reserves of both [2]. The UAE is one of the main oil-exporting countries and is a member of OPEC [3]. It deliberately considers oil exports as the main source of income for budget financing. The UAE's economy has several characteristics that set it apart from most developing economies, including the introduction of a free economy and its dependence on oil and foreign labour [4].

Since the mid-1970s, thanks to oil exports, the United Arab Emirates has experienced rapid economic and social development, which has led to high levels of economic growth [4]. Thus, the increased level of income has contributed to an increased level of consumption and standard of living in the country. All sectors of the economy, productivity, and services have achieved relatively high growth rates, which have directly contributed to increased rates of macroeconomic growth. However, low oil prices and austerity measures continue to weigh on the UAE economy [5].

Thanks to its oil sector, the UAE's GDP increased from USD 103 billion in 2001 to USD 359 billion in 2020—an increase of 348.5%. Owing to fluctuations in world oil prices, its GDP exhibited average annual changes within the range of ± 70% during this period (Figure 1).

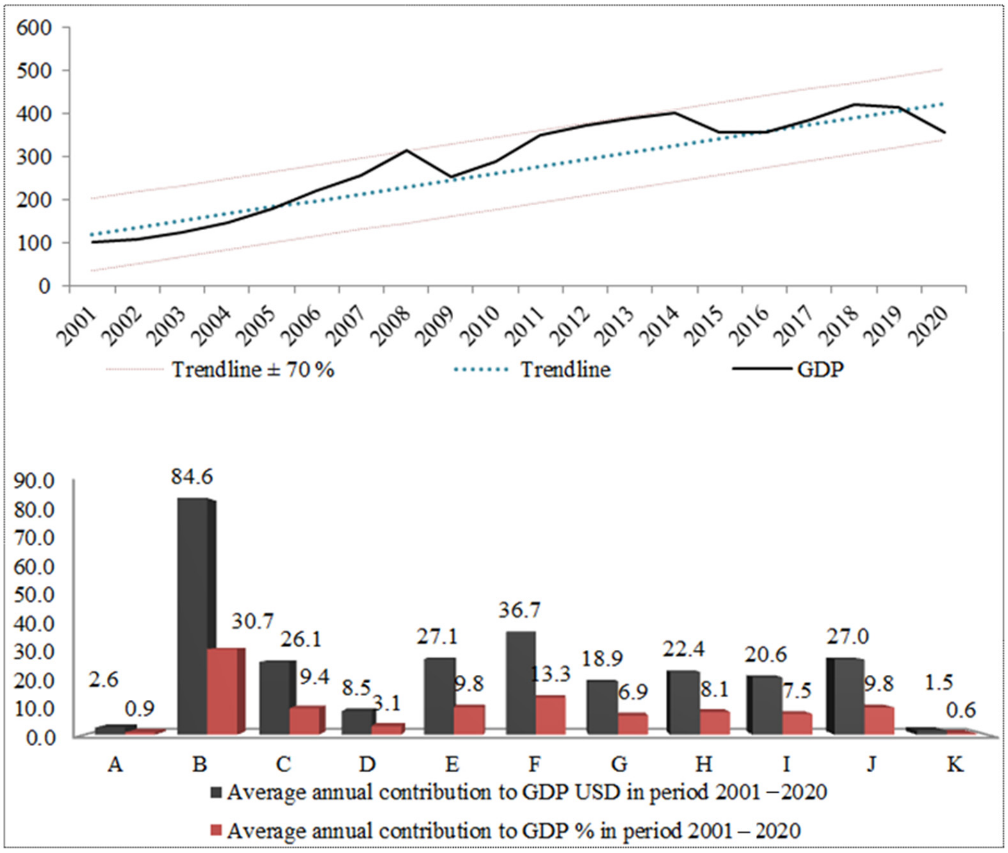


Figure 1. UAE total GDP broken down by economic sector for the period of 2001–2020. A: agriculture, livestock, and fishing; B: mining and extractive industries; C: manufacturing industries; D: electricity, gas, and water supply; E: construction; F: wholesale and retail trade and repairing services; G: transport, storage, and communications; H: corporate finance; I: real estate and business services; J: government services, etc.; K: domestic (consumer) services.

In 2014, the UAE's GDP reached a peak of USD 403 billion, with growth primarily driven by the oil sector. The mining and other extractive industries (including crude oil and natural gas) account for an average of USD 84.6 billion per year (30.7% of the UAE's GDP). The oil industry plays a more significant role in the economy than other sectors.

Thus, the economy of the United Arab Emirates, as an important oil producer and exporter is considerably affected by current events in the global oil markets. In modern conditions, sharp fluctuations in oil prices [6–12] are a very common occurrence in the global economic sphere, leading to unrest and economic turmoil in the world's energy markets, especially for oil-exporting countries such as the UAE. Between 1976 and 2012, world oil prices rose from USD 12.8/barrel to USD 111.63/barrel as a result of increasing global energy demand [13]. Most striking among these fluctuations is the sharp drop in the oil price in 2008 and its resumption after the financial crisis [14].

According to the statistics of the U.S. Energy Information Administration (2021), from June 2012 to March 2016, the average annual price of Brent crude oil fell from USD 111.63/barrel to USD 43.64/barrel [15], which negatively affected the economies of oil-exporting countries. Since the middle of 2014, owing to the oversupply of energy commodities and the decline in global demand, oil prices have exhibited significant changes [6], as shown in Figure 2.

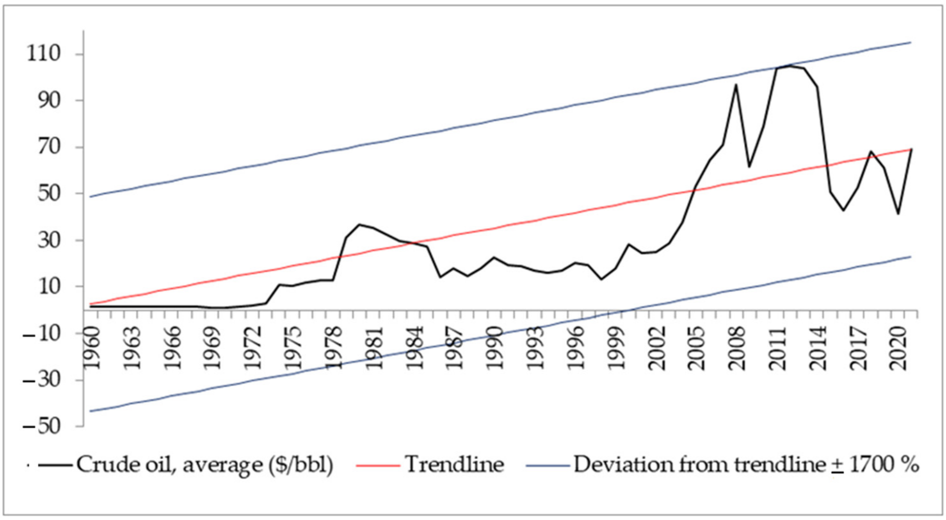


Figure 2. Average annual crude oil price from 1960 to 2021 (USD per barrel).

The factors behind the latest drop in oil prices are different. From the point of view of the World Bank (2015), the recent drop in oil prices was caused by many factors, including several years of unexpected growth in unconventional oil production, weakening global demand [16], a significant shift in OPEC policy [17–20], the removal of some geopolitical risks [21], and the appreciation of the US dollar [22]. From the Bank of Canada's perspective, supply and demand factors played a significant role in the sharp decline in oil prices in 2014. Long-term production responses to a period of rising oil prices, an unexpected increase in shale oil production in the United States, and OPEC's decision to maintain production levels all played a key role in the initial drop in oil prices [23].

However, owing to the large financial reserves of the United Arab Emirates, this country ranked second among oil-exporting countries (13.3%) after Saudi Arabia (47.8%) in terms of monetary reserves at the level of Arab countries in 2021 [24], and low export income is not yet a serious crisis for the country's economy in the short term, although it may pose a real threat to economic security in the long term. Moreover, the fall in oil prices has directly affected the economies of oil-producing countries such as Iran and Russia [25].

In addition, global oil prices are linked to many factors, which can be divided into three main sections as follows. Some of them are related to global events such as wars and disasters [25–28], as well as economic sanctions [29]. For example, the war in Syria has had a considerable impact on the political relations between countries and has thus negatively affected oil-exporting countries. Economic sanctions are also in place against countries with large oil reserves, such as Iran [30] and Venezuela.

Oil-exporting countries can play an important role in world oil prices through the formation of regional or international organizations that determine the priorities of oil-exporting countries and make decisions about global oil prices and production quantities, such as OPEC, which plays an important role in global oil markets and global financial markets [31].

According to Sánchez [32], Munasinghe [33], and Dunkerley and Ramsay [34], oil-importing countries can reduce or increase the volume of petroleum products, which has a direct impact on world oil prices. They can also choose the countries from which they can import petroleum products.

Moreover, geopolitical effects play an important role in the economies of oil-exporting countries, including the Gulf Cooperation Council countries. A study by Alqahtani and Klein [35] revealed that each GCC country responds differently to shocks in terms of geopolitical uncertainty. The same results were obtained in a study by Ben Cheikh et al. [36].

Following the launch of the oil industry at a commercial scale in 1960, the UAE began to rely on this sector, causing a decline in the importance of other economic sectors. This led to what is known as Dutch disease, a situation in which the growth or boom in one sector causes and coexists alongside a decline in other sectors [37]. This disease can be considered a major feature of the UAE's economic growth [38].

Among the obstacles to the development of the UAE's oil sector and its position as a major oil exporter is climate change, which has played a key role in the gradual global transition away from non-renewable energy sources towards clean renewable energy sources. Motivated by considerations of energy security as much as climate change, oil-producing nations are pursuing diverse energy strategies [39]. From our point of view, the oil sector is still the main engine of the global economy, but its role is gradually declining as alternative energy sources are developed. The UAE has put into effect a range of measures to reduce its dependence on the oil sector and progressively increase the efficiency of other economic sectors, such as industry, agriculture, and trade (including re-export).

The factors that affect global oil prices make the UAE's economy vulnerable to considerable risks, the most important of which is a decline in the county's main source of income. Moreover, these risks are not subject to control. Therefore, in this study, we sought to determine the mechanism of the impact of fluctuations in international oil prices on the UAE's economy by building an appropriate mathematical model, which may help to establish future plans for the UAE.

2. Theoretical Background

The macroeconomic consequences of changing oil prices are causing considerable controversy in the formulation of economic policies in oil-exporting countries. In this regard, many studies have investigated macroeconomic models of the impact of changes in world oil prices using a wide range of macroeconomic indicators [40–42]. In general, these studies have focused on finding mathematical models that reflect the cost of the economic impact of any fluctuations in international oil prices on various economic indicators [43].

The main purpose of macroeconomic modelling is to study the causal relationship between variables, whether in the short or long term. Tinbergen (1939) [44] was the first to develop mathematical models in this area. Since then, a large number of macroeconomic mathematical models have been developed to meet growing demand.

In theoretical and practical research, there are many mathematical models that can explain the causal relationships among variables. Scientific studies differ in terms of the models used to model the economic impact of fluctuations in global oil prices on economic indicators. The most important approaches include vector autoregression (VAR) [45], structural vector autoregression (SVAR) [46], the dynamic panel data model [47], the autoregressive moving average model (ARMA) [48], generalized autoregressive conditional heteroskedasticity (GARCH) models [49,50], and the non-linear cointegrating autoregressive distributed lag (NARL) model [51].

One of the most important studies using mathematical modelling was conducted by S.E. Shmelev and R.U. Ayres, who used a multivariate econometric model combining elements of short-term and long-term dynamics to identify the main macroeconomic factors behind the formation of wealth in the United States, including the wealth observed in the previous period, changes in market capitalization, changes in the US house price index, and inflation. On the other hand, factors such as fluctuations in oil prices, unemployment levels, and the debt-to-GDP ratio generally have a less statistically significant impact [52].

Y. He and M. Lee, who conducted research using the impulse response function for the purposes of empirical analysis, concluded that an energy price shock leads to an instantaneous drop in energy use, followed by a decline in labour supply, capital stock, and output. In contrast, they found that an energy price shock leads to increases in consumption, wages, the price of goods, inflation, and the interest rate on deposit accounts [53].

Among the important methods used to model the role of oil in a country's economy is the error correction model (ECM), which, although far from new, is still frequently used at a global level in macroeconomics research projects. For example, it was used by S.I. Humbatova and N.Q.-O. Hajiyev to test the reliability of the results in a study assessing the impact of oil on macroeconomic indicators in Azerbaijan [54]. The macroeconomic model developed by P. Adamczyk introduced the Interacted Panel VAR (IPVAR), which showed that shocks caused by volatility in oil prices have an impact on a country's employment structure and that this impact is related to the level of its dependence on energy imports and the exchange rate regime [55].

An important method used in macroeconomic modelling is the dynamic stochastic general equilibrium (DSGE) model, which is based on the applied general equilibrium theory established by L. Walras (1954) and on microeconomic principles [56]. B. Zhang, X. Ai, X. Fang, and S. Chen applied this theory to construct a DSGE model to investigate the transmission mechanism and impact effects of oil price fluctuations driven by different factors in the macroeconomy of China, the world's largest importer of crude oil. They found that the short-term decline in global oil prices caused by supply-driven pressures in the international energy markets promotes positive output growth through the positive cost effect of the supply channel and that in the long term, the production regulation cost dampens the incentive to invest in the alternative energy sector [57].

Previous studies have been concerned with explaining the nature of the relationships between oil price fluctuations and macroeconomic variables. Most studies have found that there are a linear and non-linear relationships between global oil prices and macroeconomic indicators [40,41,58–61], with all studies showing clear evidence of the non-linear relationship between oil price changes and macroeconomic variables. The determination of macroeconomic indicators is necessarily a broad-brush exercise, and there are many different approaches that can be used in relation to various macroeconomic indicators in order to reflect the economic reality of the country in question. For example, the economic scientist R. Ayres (1998) sees economic growth as an illusory and outdated concept; in his view, countries seek to raise economic growth while making little or no progress in human welfare (in terms of measurable criteria. such as healthcare, quality of diet, housing or education, leisure opportunities, etc.) [62]. However, this does not apply to the UAE, as most of these indicators are related to the country's GDP, which is heavily dependent on the crude oil sector. In this study, we therefore confine ourselves to studying the casual relationship between global oil prices and the contribution made by the UAE's extractive industries to its GDP.

Given the importance of the Middle East region as an area with large oil reserves, can changes in global oil prices and geopolitical conditions affect the economies of these countries?

Many studies that have examined the impact of international oil prices on the economies of the countries of the Middle East and North Africa. For example, [63–69] presented empirical evidence of a significant positive relationship between oil in terms of trade growth volatility and economic growth [70–72]. Some studies [73,74] have found that high oil prices lead to positive effects in the economies of the Gulf Cooperation Council countries, including the United Arab Emirates.

The United Arab Emirates is an oil-exporting country, a member of the Gulf Cooperation Council, and an OPEC countries, so any change in world oil prices will have an effect on the economic indicators of the United Arab Emirates. For example, the results of a study by Mahmah and Kandil [75] show that oil price fluctuations have a significant impact on the liquidity of banks, domestic credit, and foreign direct investment but a negligible effect on non-oil GDP growth in the UAE.

Some studies have found that to help the Gulf Cooperation Council countries out of their economic problems, it is necessary to diversify exports to compensate for losses from oil exports [76] and to minimize the effect of volatility in oil prices, leading to positive impacts on the UAE's economy. The government of the UAE should therefore reform its policies and procedures [77].

Almost of the abovementioned studies concluded that changing oil prices have a considerable impact on all economic and social sectors in oil-exporting countries. According to analyses reported in previous studies, it can be concluded that changes in global oil prices have forced oil-exporting countries to look for new sources of stable, durable, and reliable income which that would allow them to ensure their economic security despite changing conditions.

In order to find appropriate macroeconomic models for making economic decisions at the state level and to determine future strategies in the event of any fluctuations in oil prices, it is necessary to determine the causal relationships of fluctuations in oil prices and the national product of these countries.

To accurately determine the fluctuations in oil prices and understand the transmission mechanisms of their impact, it is necessary to select an appropriate mathematical model.

To study the impact of effect of global oil prices on the UAE's GDP, this research was divided into three main sections.

The first was building an appropriate mathematical model that describes the nature of the relationships among the variables. Eleven mathematical models were used in this study that are usually used in research to explain the relationships among variables. The second section involved testing the models. In this stage, the mathematical models were evaluated to obtain the best mathematical model. The selection was made on the basis of standard criteria, such as Pearson's correlation coefficient [78], Fisher's criterion, *p*-value, etc. The third part involved discussing the results.

3. Methodology and Data

In our research, we aimed to model the impact of global oil prices on macroeconomic variables in the UAE, including GDP, the non-financial corporations sector, agriculture, livestock and fishing, mining and extractive industries (including crude oil and natural gas), manufacturing industries, electricity, gas and water supply, construction, wholesale and retail trade and repairing services, transport, storage, communications, corporate finance, real estate and business services, government services, etc., and domestic (consumer) services.

We analysed annual time series data from 2001 to 2020, with 20 observations. The study was mainly based on sources of data including the statistics of the Federal Competitiveness And Statistics Authority of the UAE (national Account Estimates 2012–2021 [79] and national Account Estimates 1975–2009 [80]) and statistics of the World Bank (average annual crude oil price from 1960 to 2021 (USD per barrel) [13] and the official exchange rate (LCU per USD, period average)) [81].

In this research, we relied on the methods of linear and non-linear correlation, regression, and causality tests in order to find the appropriate model to explain the relationship between fluctuations in global oil prices and the country's macroeconomic indicators.

In order to measure the impact of changing oil prices on GDP, a mathematical model was designed based on the relative weight of the variables to separately analyse the data on changes in oil prices and GDP. Next, a comparison analysis was carried out to calculate the differences among the variables. The weighted average method (geometric mean) (Appendix A) was used to calculate the average annual causal effects among the variables during the study period.

The optimal mathematical model can characterize the relationship between changes in world oil prices and economic growth in the UAE, which can be checked at various levels as follows:

1. The level of the economic sector: do changes in world oil prices affect each economic sector separately?
2. Trade-offs between sectors: which economic sector is most influenced by changes in world oil prices?
3. The level of the country's economy as a whole: do changes in world oil prices have an impact on the country's economy as a whole?

The study of the relationship between the variables depended mainly on studying this relationship in two phases: first in the short term and then in the long term.

One of the most important methods used to measure the relationship between variables in the short term is the pairwise Granger causality test [82]. In order to determine the number of lags, we used the Schwarz information criterion (SC) [83].

However, in the long term, to build an appropriate mathematical model, the following steps were taken:

I. Unit root test;
II. Cointegration test;
III. Residual stability test;
IV. A test for the presence of statistical and economic problems in mathematical models;
V. Preliminary test of the mathematical models;
VI. Second test of the mathematical models;
VII. Selection of an appropriate mathematical model.

I. Unit Root Test:

In theory, a basic model for discovering a unit root is the Dickey–Fuller (DF) test using the likelihood ratio [84]:

$$Y_t = \rho Y_{t-1} + e_t \; Y_0 = 0 \; t = 1, 2, 3 \ldots \ldots \tag{1}$$

Adding the constant μ to the equation yields:

$$Y_t = \mu + \rho Y_{t-1} + e_t \; Y_0 = 0 \; t = 1, 2, 3 \ldots \ldots \tag{2}$$

Adding the constant μ and the deterministic time trend βt to the equation yields:

$$Y_t = \mu + \beta t + \rho Y_{t-1} + e_t \; Y_0 = 0 \; t = 1, 2, 3 \ldots \ldots \tag{3}$$

If $|\rho| = 1$, the regression coefficient between Y_t and Y_{t-1} is 1, and the time series is not stationary. If $|\rho| > 1$, the time series is not stationary, and the variance (σ^2) (i.e., NID $(0, \sigma^2)$) of the time series grows exponentially as t increases. If $|\rho| < 1$, the time series converges (as $t \to \infty$) to a stationary time series [84].

The equation of the unit root is expressed as follows:

$$\Delta Y_t = (Y_t - Y_{t-1}) = (\rho - 1)_1 Y_{t-1t} + u_t \tag{4}$$

$$\delta = (p - 1) \tag{5}$$

$$\Delta Y_t = \delta_1 Y_{t-1t} + u_t \tag{6}$$

We tested whether the variable contained a the unit root; that is, we performed the following test:

The time series is not stationary:

$$H_0 : \delta_1 = 0$$

The time series is stationary:

$$H_A : \delta_1 < 0$$

If δ_1 was less than zero, we rejected the null hypothesis of the non-stationarity of the function and concluded that the function was stationary.

To obtain a broader view, Dickey and Fuller developed a higher-order autoregressive process known as the augmented Dickey–Fuller (ADF) test [84]. This test is represented as follows:

$$\Delta Y_t = \delta_0 + \delta_1 Y_{t-1t} + \delta_2 T + \sum_{i=1}^{m} \Delta Y_{t-1} + u_t \tag{7}$$

If the equation includes decreasing values for the differences, a number of random errors can be independent (there is no self-correlation).

However, the t-values do not follow the t-table; instead, there is a special table called the Dickey–Fuller table, which was developed by MacKinnon [85]. We compared the calculated value and the critical value and rejected the null hypothesis if the calculated value was higher than the original value.

II. Cointegration Test

When using the Engle and Granger (EG) [86] and Johansen [87–89] cointegration tests, we had two requirements:

(1) The variables should be integrated to the same order. By analysing the data in the table of the cointegration relationships between global oil prices and GDP using the ARDL method, we found that all indicators were stationary after second differencing.
(2) The residuals of the estimated regression equation must be stationary. In other words, for cointegration, according to the methodology, the *residual* series must not contain a unit root.

Many scientific studies depend on the linear mathematical model in order to study the relationships between variables. However, in some circumstances, linear regression cannot explain the relationships between the variables, so most researchers resort to non-linear regression. In practice, among the most important models that have been used to determine the relationship between the dependent and independent factors are the following curve estimation models: linear, logarithmic, inverse, quadratic, cubic, power, compound, S-curve, logistic, growth, and exponential [90,91]. Moreover, in order to emphasize the linear nature of the models, the approaches used include the application of a logarithmic, such as the study by (Shmelev, S.E.; Ayres, R.U.) 2021 Al-Mawali, N.; Haslifah M.H.; Khalil A.-B (2016), or inverse scale when analysing and plotting all variables in the model's equations.

4. Empirical Analysis and Results

For the first test, the impact of fluctuations in world oil prices on the GDP of the United Arab Emirates was calculated with the following variables: Y1, the non-financial corporations sector; Y2, agriculture, livestock, and fishing; Y3, mining and quarrying (including crude oil and natural gas); Y4, manufacturing industries; Y5, electricity, gas, and water; Y6, construction; Y7, wholesale retail trade and repair services; Y8, transport, storage, and communication; Y9, the financial corporations sector; Y10, real estate and business services; Y11, government services sector and others; Y12, domestic services to households; Y13, total GDP; Y14, total of the non-oil sectors; X, world oil prices.

For the second test on the impact of the mining and quarrying sector on the GDP of the United Arab Emirates, the following variables were used: Y1, the non-financial corporations sector; Y2, agriculture, livestock, and fishing; Y3, manufacturing industries; Y4, electricity, gas, and water; Y5, construction; Y6, wholesale retail trade and repair services; Y7, transport, storage, and communication; Y8, the financial corporations sector; Y9, real estate and business services; Y10, government services sector and others; Y11, domestic services to households; Y12, total GDP; Y13, total of the non-oil sectors; X1, mining and quarrying (including crude oil and natural gas).

The pairwise Granger causality tests (Table 1) indicated that in the short term, global oil prices caused changes in the GDP and the oil sector, whereas global oil prices did not cause changes in the UAE's non-oil sector.

Table 1. Pairwise Granger causality test results (lags: 2).

Null Hypothesis:	F-Statistic	Prob.
X1 does not Granger-cause Y13	65.0442	0.00
X1 does not Granger-cause Y14	3.42265	0.06
X1 does not Granger-cause Y3	145.984	0.00

In order to detect unit roots, we used the residual-based ADF test for stationary cointegration as follows.

For Test 1 (Figure 3):

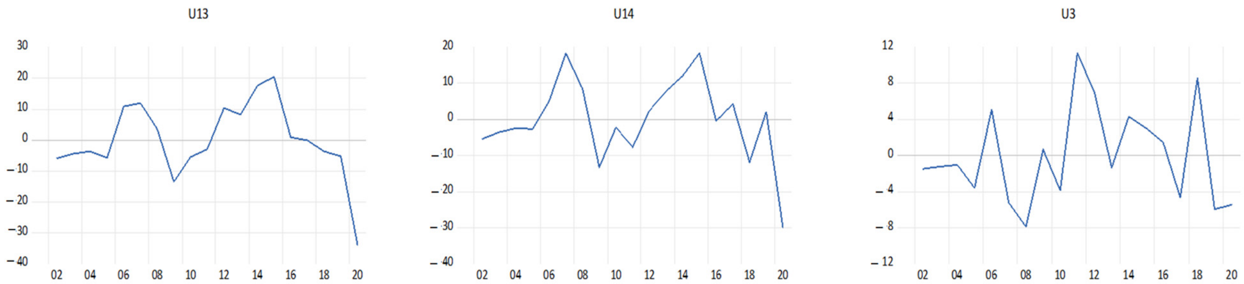


Figure 3. The residual-based ADF test for Test 1.

Residual U13 for oil prices: x1 → GDP Y13;
Residual U14 for oil prices: x1 → non-oil GDP Y14;
Residual U3 for oil prices: X1 → mining and quarrying (including crude oil and natural gas) Y3.

For Test 2 (Figure 4):

Residual U1 for X: mining and quarrying (including crude oil and natural gas) → Y1 the non-financial corporation sector: U1;
Residual U2 for X: mining and quarrying (including crude oil and natural gas) → Y2 agriculture, livestock, and fishing;
Residual U3 for X: mining and quarrying (including crude oil and natural gas) → Y3 manufacturing industries;
Residual U4 for X: mining and quarrying (including crude oil and natural gas) → Y4 electricity, gas, and water;
Residual U5 for X: mining and quarrying (including crude oil and natural gas) → Y5 construction;
Residual U6 for X: mining and quarrying (including crude oil and natural gas) → Y6 wholesale retail trade and repair services;
Residual U7 for X: mining and quarrying (including crude oil and natural gas) → Y7 transport, storage, and communication;
Residual U8 for X: mining and quarrying (including crude oil and natural gas) → Y8 the financial corporation sector;
Residual U9 for X: mining and quarrying (including crude oil and natural gas) → Y9 real estate and business services;
Residual U10 for X: mining and quarrying (including rude oil and natural gas) → Y10 government services sector and others;
Residual U11 for X: mining and quarrying (including crude oil and natural gas) → Y11 domestic services to households;
Residual U12 for X: mining and quarrying (including crude oil and natural gas) → Y12 total GDP;
Residual U13 for X: mining and quarrying (including crude oil and natural gas) → Y13 total of non-oil sectors.

The graphs show that the residuals were almost stable. To ensure that the residuals were stable at the first level (i.e., the time series did not contain a unit root), we applied the augmented Dickey–Fuller (ADF) test, for which the results are shown in Tables 2 and 3.

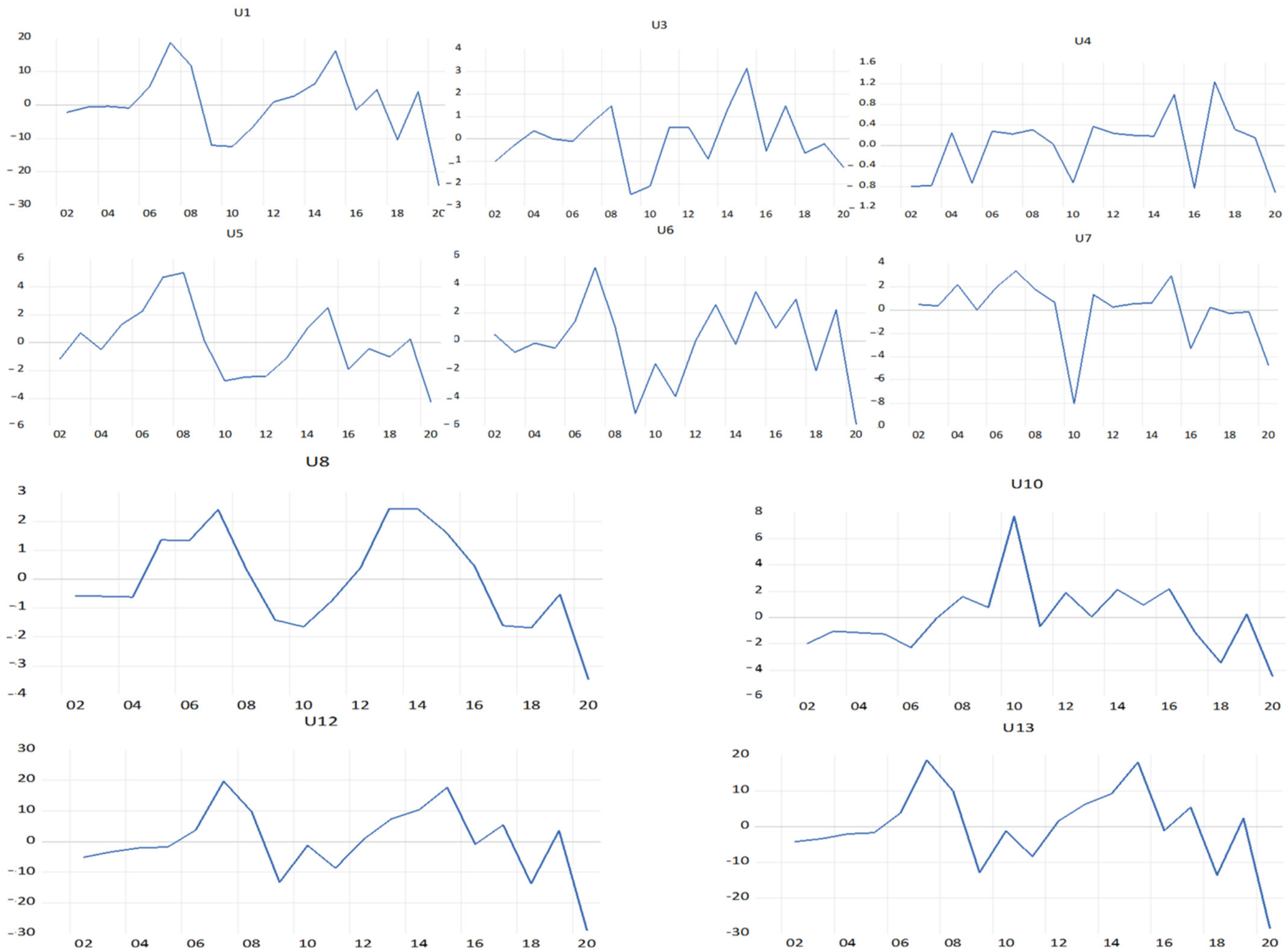


Figure 4. The residual-based ADF test for Test 2.

Table 2. Augmented Dickey–Fuller (ADF) test results for unit roots with a 0.05 significance level.

Test 2	Test 1	Level			1st Difference (1st)			2nd Difference (2d)			Stationarity in Difference
		None	Trend and Intercept	Intercept	None	Trend and Intercept	Intercept	None	Trend and Intercept	INTERCEPT	
-	X1	−0.20	−2.08	−2.24	−3.98	−3.97	−3.88	−5.63	−5.22	−5.43	2 d
X	-	−0.47	−1.30	−1.81	−3.58	−3.56	−3.47	−5.62	−3.83	−4.05	2 d
Y1	Y1	0.67	−1.07	−1.88	−3.13	−4.73	−3.28	−3.86	−3.89	−4.10	2 d
Y2	Y2	0.35	−2.47	−1.97	−6.30	−6.05	−6.23	−4.31	−3.97	−4.16	2 d
-	Y3	−0.47	−1.30	−1.81	−3.58	−3.56	−3.47	−5.62	−3.83	−4.05	2 d
Y3	Y4	1.54	−3.54	−1.33	−2.58	−4.56	−4.55	−5.58	−5.31	−5.39	2 d
Y4	Y5	1.24	−2.73	1.24	−0.78	−2.74	−3.09	−4.74	−4.72	−4.51	2 d
Y5	Y6	−0.09	−1.29	−2.44	−1.78	−2.52	−1.76	−3.01	−3.00	−2.92	2 d
Y6	Y7	1.00	−2.48	−1.32	−1.96	−2.44	−2.49	−3.17	−3.04	−3.07	2 d
Y7	Y8	0.15	−1.41	−2.36	−2.52	−3.31	−2.54	−4.00	−3.80	−3.92	2 d
Y8	Y9	−0.44	−2.44	−1.80	−1.42	−1.99	−1.76	−2.42	−2.70	−2.37	2 d
Y9	Y10	−0.44	−3.00	−3.21	−3.30	−3.26	−3.21	−4.21	−3.92	−4.08	2 d
Y10	Y11	1.00	−0.98	−0.84	−0.99	−1.19	−1.34	−3.96	−4.34	−3.83	2 d
Y11	Y12	1.39	−1.74	0.13	−2.74	−3.73	−3.29	−4.58	−4.31	−4.42	2 d
Y12	Y13	0.77	−0.89	−1.57	−1.26	−2.13	−1.88	−3.39	−3.58	−3.30	2 d
Y13	Y14	0.52	−1.11	−1.94	−2.46	−3.72	−2.99	−4.11	−3.93	−3.98	2 d

Table 3. The unit root test for residuals according to the ADF test (Tests 1 and 2).

Test 1			
Resd.	U13	U14	U3
t-Statistic (level 5%)	−3.110289	−2.472939	−4.290669
Probability	0.0040	0.0167	0.0002
Results Level	Stationary 5%	Stationary 5%	Stationary 5%

Test 2										
Resd.	U1	U3	U4	U5	U6	U7	U8	U10	U12	U13
t-Statistic	−2.69	−3.90	−5.03	−2.02	−3.56	−4.06	−3.514947	−3.41	−2.90	−2.86
Probability	0.0102	0.0006	0.0000	0.0443	0.0013	0.0004	0.0698	0.0019	0.0062	0.0069
Result Level	Stationary 5%	Stationary 5%	Stationary 5%	Stationary 5%	Stationary 5%	Stationary 5%	Stationary 10%	Stationary 5%	Stationary 5%	Stationary 5%

Based on analysing and plotting all regression models and in order to improve the features of linearity of the models as one of the methods used to resolve these problems, we transformed all variables in the model equations to logarithmic models in the form of *Y:* (log *Y*) → X: (log X) or to inverse models *Y:* (log *Y*) → X: (1/log X). We then ran the linear models in R again.

For Tests 1 and 2, to solve the variance problem, we converted the mathematical model to a logarithmic model:

$$\log(y) = a + b\log(x) + ei \tag{8}$$

or an inverse model:

$$\log(y) = a + b/\log(x) + ei \tag{9}$$

For Test 1, after transforming all the linear models to logarithmic models, we obtained the results shown in Table 4.

Table 4. Results of the regression (Test 1).

Independent Variable	**Log(Y13)**		**Log(Y3)**		**Log(Y14)**	
Dependent variable	log(X1)	1/log(X1)	log(X1)	1/log((X1)	log(X1)	1/log(X1)
R-squared	0.907894	0.866802	0.970741	0.944943	0.631302	0.617883
Adjusted R-squared	0.895613	0.849042	0.966840	0.937602	0.582143	0.566935
S.E. of regression	0.049215	0.059183	0.069775	0.095713	0.049373	0.050264
Sum squared residual	0.036331	0.052540	0.073027	0.137416	0.036566	0.037896
Log likelihood	30.30811	26.98808	24.02474	18.33513	30.25027	29.92853
F statistic	73.92754	48.80717	248.8321	128.7232	12.84187	12.12752
Prob (F statistic)	0.000000	0.000000	0.000000	0.000000	0.000562	0.000735
Mean dependent var	−0.011973	−0.011973	−0.023708	−0.023708	−0.008779	−0.008779
S.D. dependent var	0.152325	0.152325	0.383168	0.383168	0.076380	0.076380
Akaike information criterion	−3.034234	−2.665343	−2.336082	−1.703903	−3.027808	−2.992059
Schwarz criterion	−2.885839	−2.516947	−2.187687	−1.555508	−2.879412	−2.843664
Hannan–Quinn criterion	−3.013772	−2.644881	−2.315620	−1.683442	−3.007346	−2.971597
Durbin–Watson statistic	2.088651	2.110428	2.530295	2.603950	1.627530	1.618978
Choose the model (See Appendix A)	Yes	No	Yes	No	Yes	No

For Test 2, after transforming all linear models to inverse models, we obtained the results presented in Table 5.

Table 5. Results of the regression (Test 2).

Independent Variable	Log(Y1)	Log(Y3)	Log(Y4)	Log(Y5)	Log(Y6)	Log(Y7)	Log(Y8)	Log(Y10)	Log(Y12)	Log(Y13)
Dependent variable	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)	1/log(X)
R-squared	0.92	0.78	0.45	0.36	0.57	0.61	0.22	0.63	0.64	0.92
Adjusted R-squared	0.91	0.75	0.37	0.28	0.51	0.55	0.11	0.58	0.59	0.91
S.E. of regression	0.05	0.05	0.14	0.08	0.07	0.13	0.07	0.10	0.05	0.05
Sum squared residual	0.03	0.05	0.29	0.10	0.08	0.24	0.07	0.14	0.04	0.03
Log likelihood	30.95	28.36	11.60	21.16	23.13	13.28	23.89	17.99	30.49	31.76
F statistic	91.56	26.12	6.02	4.26	9.78	11.60	2.06	12.66	13.38	88.17
Prob (F-statistic)	0.00	0.00	0.01	0.03	0.00	0.00	0.16	0.00	0.00	0.00
Mean dependent var	−0.01	0.00	0.00	−0.01	−0.01	−0.02	−0.01	0.00	−0.01	−0.01
S.D. dependent var	0.16	0.11	0.18	0.10	0.10	0.19	0.07	0.15	0.08	0.15
Akaike information criterion	−3.11	−2.82	−0.96	−2.02	−2.24	−1.14	−2.32	−1.67	−3.05	−3.20
Schwarz criterion	−2.96	−2.67	−0.81	−1.87	−2.09	−0.99	−2.17	−1.52	−2.91	−3.05
Hannan–Quinn criterion	−3.09	−2.80	−0.94	−2.00	−2.22	−1.12	−2.30	−1.65	−3.03	−3.17
Durbin–Watson statistic	1.52	1.88	3.12	1.73	1.51	1.44	1.82	1.88	1.52	1.57
Choose the model (See Appendix A)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

After analysing the data in the tables, we found that the logarithmic and inverse models were best at solving the variance problem.

According to the properties of the logarithmic function and taking into account the fact that the time series are stable at the second difference, the difference model takes the following form:

$$\text{Log}Y - \text{Log}Y_{t-2} = \beta 0 + \beta 1 * (\text{Log}X - \text{Log}X_{t-2}) + \text{U}(-1) \tag{10}$$

where t−2 is the second difference for the time series of the variable.

It can be converted to the following form:

$$\text{Log}(\frac{Y}{Y_{t-2}}) = \beta_0 + \beta_1 * \text{Log}(\frac{X}{X_{t-2}}) + \text{U}(-1) \tag{11}$$

We therefore built the following log-linear regression model equations and measured the impact of oil prices on the UAE's economy (Test 1), as well as the impact of the oil sector on the UAE's economy (Test 2):

For Test 1, the models were:

$$\text{Log}(\frac{Y13}{Y13_{\ t-2}}) = 0.0011890592699 + 0.396255332564 * \text{Log}(\frac{X1}{X1_{t-2}}) - 0.00188867587498 * \text{U13}(-1) \tag{12}$$

$$\text{Log}(\frac{Y3}{Y3_{\ t-2}}) = 0.00401193640647 + 1.04685972182 * \text{Log}(\frac{X1}{X1_{t-2}}) - 0.00767021985217 * \text{U3}(-1) \tag{13}$$

$$\text{Log}(\frac{Y14}{Y14_{\ t-2}}) = 0.000754315572314 + 0.130222818517 * \text{Log}(\frac{X1}{X1_{t-2}}) - 0.00383329933505 * \text{U14}(-1) \tag{14}$$

For Test 2, the models were:

$$\text{Log}(\frac{Y1}{Y1_{t-2}}) = 0.00069398673434 - 7.85786419837 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.00287918244897 * \text{U1}(-1) \tag{15}$$

$$\text{Log}(\frac{Y3}{Y3_{\ t-2}}) = 0.00707068665554 - 4.16221770325 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.00366564163213 * \text{U1}(-1) \tag{16}$$

$$\text{Log}(\frac{Y4}{Y4_{\ t-2}}) = 0.00789885514644 + 1.64329397097 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.196737549061 * \text{U4}(-1) \tag{17}$$

$$\text{Log}(\frac{Y5}{Y5_{t-2}}) = 0.000239541556519 - 1.25673877436 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.0212520482092 * \text{U5}(-1) \tag{18}$$

$$\text{Log}(\frac{Y6}{Y6_{\ t-2}}) = -0.00120235682246 - 2.39412965269 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.0246917238809 * \text{U6}(-1) \tag{19}$$

$$\mathrm{Log}(\frac{Y7}{Y7_{\ t-2}}) = -0.00568854203755 + 1.20056711895 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.0585179015798 * \mathrm{U7}(-1) \quad (20)$$

$$\mathrm{Log}(\frac{Y8}{Y8_{\ t-2}}) = -0.00866519751348 + 0.0289470707909 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.0238691075287 * \mathrm{U8}(-1) \quad (21)$$

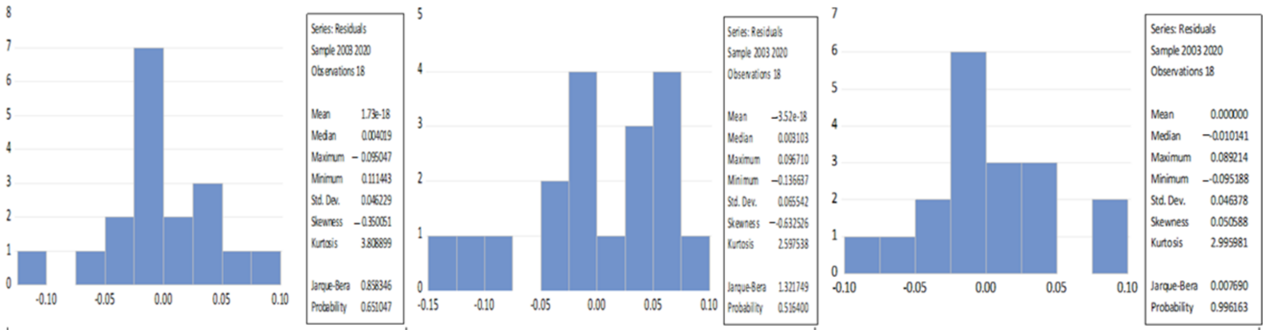
$$\mathrm{Log}(\frac{Y10}{Y10_{\ t-2}}) = 0.0115297358791 - 3.70591865829 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.0420948333954 * \mathrm{U10}(-1) \quad (22)$$

$$\mathrm{Log}(\frac{Y12}{Y12_{\ t-2}}) = 0.000743083538639 - 2.31038624937 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.00410961363405 * \mathrm{U12}(-1) \quad (23)$$

$$\mathrm{Log}(\frac{Y13}{Y13_{\ t-2}}) = 0.00148683980781 - 7.45835357283 * (\frac{1}{\log X} - \frac{1}{\log X_{t-2}}) - 0.00257622606153 * \mathrm{U13}(-1) \quad (24)$$

To test for heteroskedasticity in a linear regression model, several methods can be used. One of these methods is the Breusch–Pagan–Godfrey test [92], which tests whether the variance of the errors of a regression is dependent on the values of the independent variables. In that case, heteroskedasticity is present [93].

Figures 5 and 6 show the results of the test detecting the variance of the errors with the Breusch–Pagan–Godfrey heteroskedasticity test.



F-statistic	3.213355	F-statistic	0.006034	F-statistic	10.02677
Obs*R-squared	5.398906	Obs*R-squared	0.014469	Obs*R-squared	10.29750
Scaled explained SS	5.265619	Scaled explained SS	0.008026	Scaled explained SS	7.136670
Prob. F(2,15)	0.0689	Prob. F(2,15)	0.9940	Prob. F(2,15)	0.0017
Prob. Chi-Square(2)	0.0672	Prob. Chi-Square(2)	0.9928	Prob. Chi-Square(2)	0.0058
Prob. Chi-Square(2)	0.0719	Prob. Chi-Square(2)	0.9960	Prob. Chi-Square(2)	0.0282

Figure 5. Results of the Breusch–Pagan–Godfrey heteroskedasticity test for Test 1.

By analysing the data in the graphs, we found that heterogeneity in the mathematical models did not exist. In other words, there were no measurement problems in the mathematical models. Therefore, the mathematical models could be used for mathematical predictions

Forecasting and Discussion

To forecast macroeconomic indicators for the UAE, we used predictive crude oil price data issued by the World Bank and the U.S. Energy Information Administration for the period of 2022–2025, as shown in Figure 7.

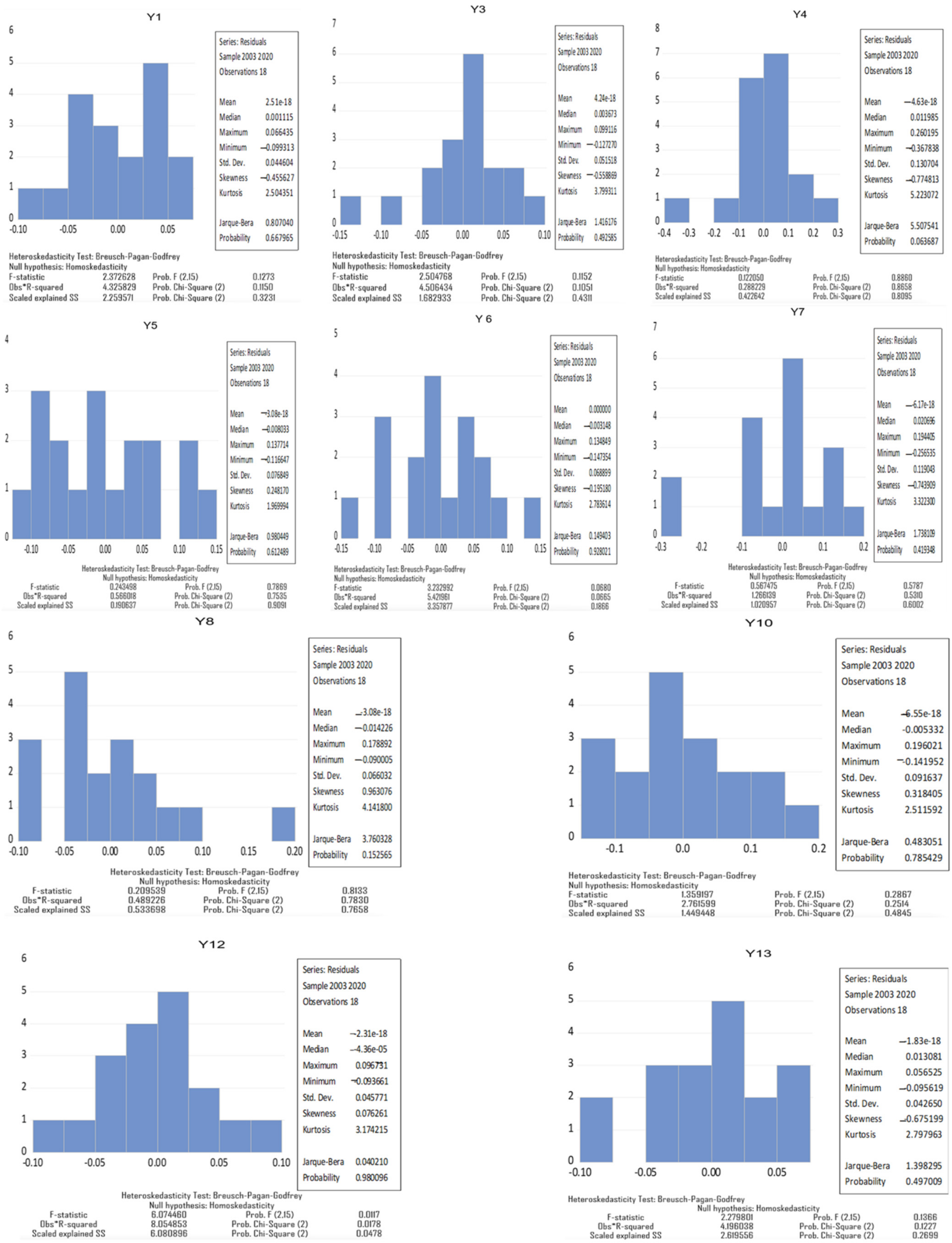


Figure 6. Results of the Breusch–Pagan–Godfrey heteroskedasticity test for Test 2.

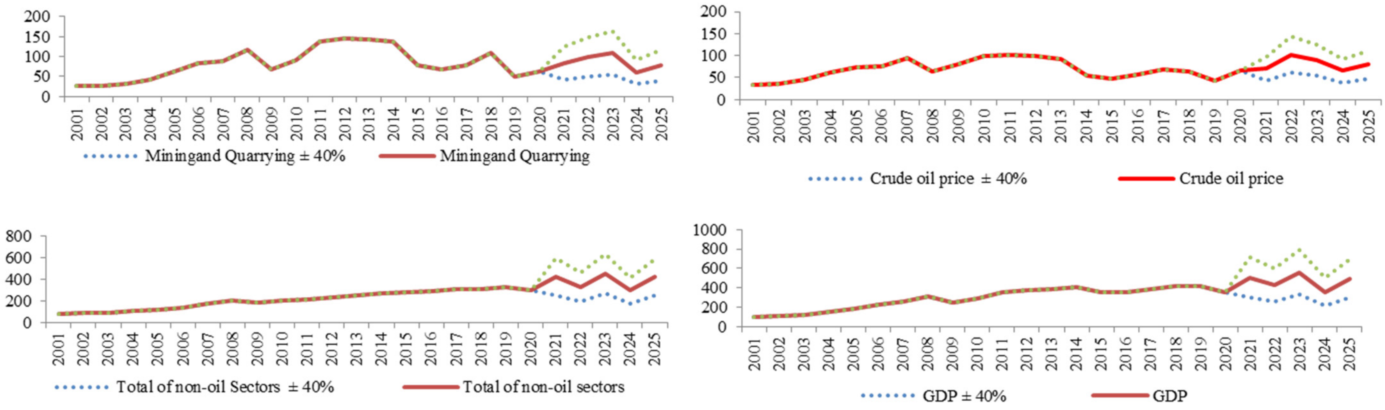


Figure 7. Forecasting results on the UAE macroeconomic indicators; the dependent variable is the crude oil price.

Using the data in the previous graphs, we can predict the macroeconomic indicators of the UAE by taking into account the impact of global oil prices and the mining and quarrying (including crude oil and natural gas) sector on these indicators, as shown in Figure 8.

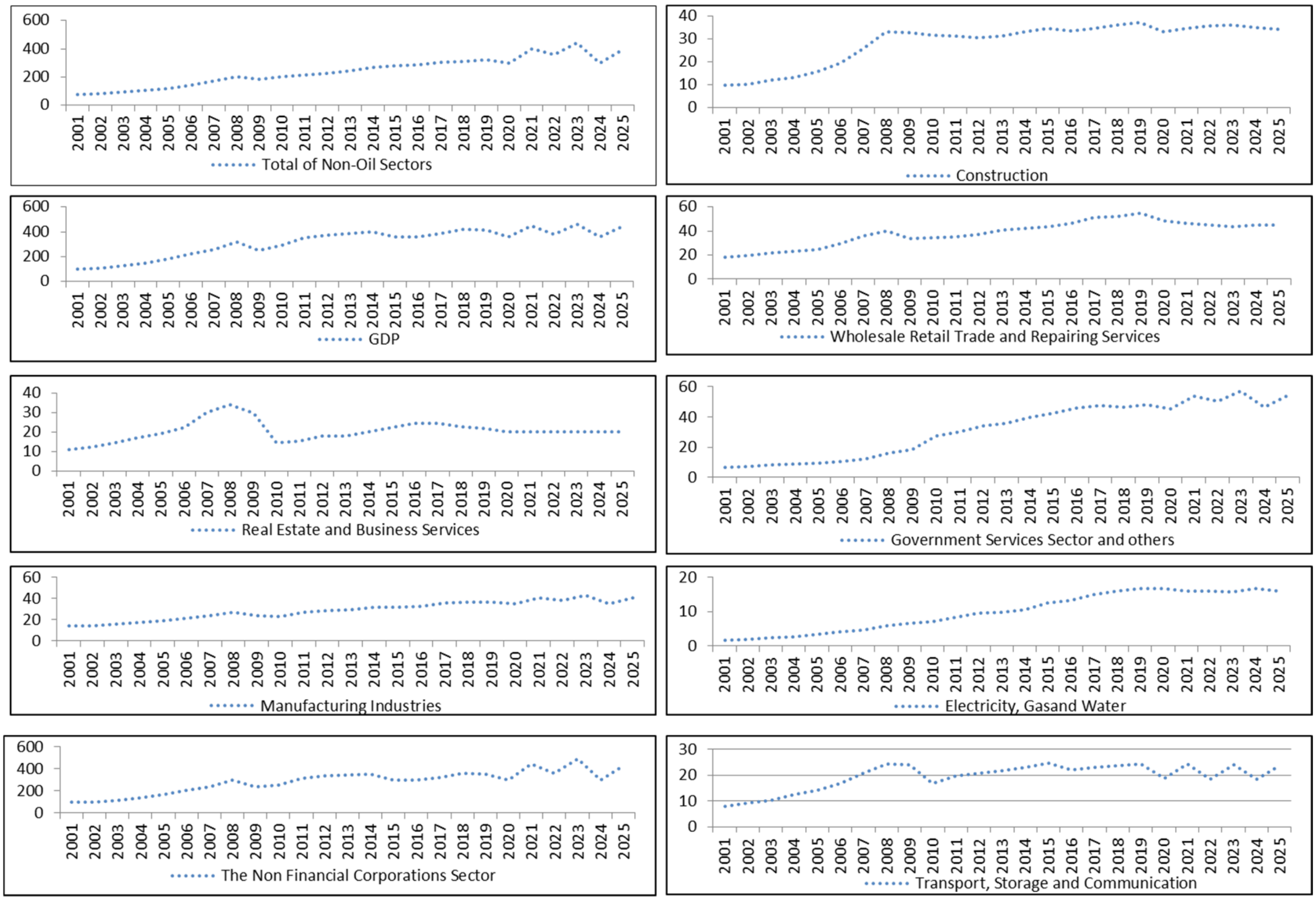


Figure 8. Forecasting results of the UAE macroeconomic (independent) variables, dependent variable mining and quarrying (including crude oil and natural gas).

In our research, models representing the long-term impact of the mining and extractive industries (including crude oil and natural gas) on the agriculture, livestock, and fishing sector; the financial corporations sector; and the government services sector were excluded, as the residuals of these models are not stationary, i.e., they do not correspond to a standard distribution.

The branching results suggest that, given a USD 5 increase in global oil prices, the UAE would increase the output of the mining and resource extraction (including crude oil and natural gas) industries by USD 22.297 billion, its total GDP would increase by USD 150,467 billion, and the total output of its non-oil sectors would increase by USD 128,170 billion.

An increase of UDS 1 million in the output of the mining and extractive industries (including crude oil and natural gas) would increase the output of the UAE's other sectors as follows: manufacturing, by USD 3.72 million; construction, by USD 0.57 million; transport, storage, and communication, by USD 5.46 million; real estate and business services, by USD 0.09 million; and the government services sector, etc., by USD 5.42 million, resulting in a total increase of USD 72.41 million in its overall GDP and a USD 61.50 million increase in the output of non-oil sectors. However, electricity, gas, and water supply would decrease by USD 0.24 million, and wholesale and retail trade and repairing services would decrease by UDS 1.23 million.

From the previous charts, we can conclude that the macroeconomic indicators of the UAE are related to fluctuations in global crude oil prices. These prices are subject to sudden and ambiguous fluctuations in international oil prices resulting from various factors; for forecasting purposes allowance was made for price deviations of $\pm$ 40%.

The largest impact was that of global oil prices (GOP) on the UAE's oil sector. There was not an important impact of GOP on the non-oil sectors of the UAE. We also noted that there was a close correlation between the UAE's oil sector and other economic sectors of the United Arab Emirates. This phenomenon can be explained by the cumulative effect, which is transmitted from fluctuations in the international oil prices to the UAE's oil sector and to other economic sectors of the UAE.

The models show the mechanism of the transmission of the impact of fluctuations in international oil prices on the economic sectors of the UAE through the UAE's oil sector.

Previous models can help economists, researchers, and academics interested in understanding and determining the mechanism of transmission of the hidden (or sequential) effects of independent variables on the dependent variables through intermediate variables.

Limitations of the study: The data used in this study relate to a time period of 20 years, from 2001–2020, and the mathematical models used in the study may not be appropriate for a different time period. The data required for this study were not fully available, and the lack of certain data may have an impact on the study results. The predictive data used in this study may not correspond to actual future data in relation to a number of factors, both specific and non-specific, that may be affected by international oil prices and that may thus affect the results of the study.

5. Conclusions

In this study, we modelled the impact of fluctuations in global oil prices in the current context of the global energy market on the UAE's gross domestic product in general and on the main economic sectors of the UAE, which include the non-financial corporation sector; agriculture, livestock, and fishing; mining and quarrying (including crude oil and natural gas); manufacturing industries; electricity, gas, and water construction; wholesale retail trade and repair services; transport, storage, and communication; the financial corporations sector; real estate and business services; government services sector and others; domestic services to households; and the total of non-oil sectors. This research was divided into two main parts: the first was a study of the impact of changes in international oil prices on the economic sectors of the UAE, and the second was a study of the impact of the oil sector on the non-oil economic sectors of the UAE.

We developed 14 simple macroeconomic models: 3 models that represent the impact of changes in oil prices on the UAE's economic sectors and 11 representing the impact of the mining and quarrying sector (including crude oil and natural gas) on the UAE's economic sectors. These models can help policymakers in UAE to establish economic plans and predict the future of the UAE's economy.

The results of this research prove the existence of a causal relationship in the short and long term between fluctuations in international oil prices and the UAE's oil sector on the one hand and between the total gross domestic product and the UAE's economic sectors on the other hand. The results of this research indicate that a rise in international oil prices and the development of the oil sector of the UAE will stimulate growth in the UAE's GDP and the other economic sectors and vice-versa. However, variations in crude oil prices will have an impact on the UAE's macroeconomic indicators; a USD 5 increase in global oil prices will result in a USD 22.297 billion increase in the output of its mining and resource extraction (including crude oil and natural gas) industries, as well as an increase of USD 150.467 billion in its total GDP.

An increase of USD 1 million in the output of the mining and extractive industries (including crude oil and natural gas) would increase the output of the UAE's other sectors as follows: manufacturing, by USD 3.72 million; construction, by USD 0.57 million; transport, storage, and communication, by USD 5.46 million; real estate and business services, by USD 0.09 million; and the government services sector, etc., by USD 5.42 million, resulting in a total increase of USD 72.41 million in its overall GDP and a USD 61.50 million increase in the output of non-oil sectors. However, electricity, gas, and water supply would decrease by USD 0.24 million, and wholesale and retail trade and repairing services would decrease by USD 1.23 million.

Taking into account the global oil price forecasts provided by the World Bank, the results of this study suggest that given an increase in crude oil prices to USD 102, the contribution of the oil sector's activities to the GDP may increase from 14.65% to 27.33%, whereas given a possible decrease in crude oil prices to USD 65.4 in 2025, such a contribution could decrease to 16.88%.

The results of this study emphasise that it is necessary to move the economy of the United Arab Emirates from the rentier economy stage to a diversified economy in order to avoid any acute and unexpected crises that may occur in global energy prices and thus ensure the economic security of the country by finding alternative options, such as developing the industrial, agricultural, and service sectors, which will be the basis for reducing dependence on the crude oil sector.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

In theory, the closeness of the relationship with linear, non-linear dependencies can be measured using the Pearson correlation coefficient [78] as follows:

$$R2 = (\mathrm{cov}(x, y)/\sigma x^{*}\sigma y)^2 \quad (A1)$$

$$P(x, y)^2 = \sigma^2 yx/\sigma^2 y \quad (A2)$$

where R (X, Y) is the correlation between the variables X and Y in the linear regression, ρ (X, Y) is the correlation between the variables X and Y in the non-linear regression, Cov (X, Y) is the covariance between the variables X and Y, σX is the standard deviation of variable

X, σY is the standard deviation of the variable Y, σ_y^2 is the total variance of the effective indicator reflecting the cumulative influence of all factors, σ_{xy}^2 is the factorial variance of the effective trait, and R (x, y) 2, ρ (x, y) 2 indicates the causality (determination), i.e., the extent to which the value of the effective attribute is due to the influence of the factor.

The calculated value of the F criterion for the linear (F1) and non-linear (F2) regression equations can be obtained according to the following formulae:

$$F1 = \frac{R^2 * (n-2)}{1-R^2} \quad (A3)$$

$$F2 = \frac{R^2 * (n-m-1)}{(1-R^2) * m} \quad (A4)$$

where m is the number of parameters in the equation, and n is the total number of observations.

To compare models, the maximization of the coefficient of determination (R^2) is among the research strategies frequently used to assess which model provides the best fit to the data [94]. Thus, an adequate model could be chosen on this basis. This is also largely related to the Fisher criterion; the greater Fvalue is than Ftable, the more adequate the model is. We used the equations below.

For linear regression:

$$X_r = R^2{}_x / R^2{}_{max} \quad (A5)$$

$$X_f = F_x / F_{max,} \quad (A6)$$

For non-linear regression:

$$X_r = \mathbf{P}^2{}_x / \mathbf{P}^2{}_{max} \quad (A7)$$

$$X_f = F_x / F_{max} \quad (A8)$$

By combining the last two equations using the multidimensional comparison method, we obtained the equations below.

For linear regression:

$$K_{(r,f)} = \sqrt{\left\{\frac{R^2{}_i}{R^2{}_m}\right\}^2} * \sqrt{[(R^2{}_i * (n-2))/(1-R^2{}_i)]/[(R^2{}_m * (n-2))/(1-R^2{}_m)]^2} \quad (A9)$$

For non-linear regression:

$$K_{(p,f)} = \sqrt{\left\{\frac{\rho^2{}_i}{\rho^2{}_m}\right\}^2} = \sqrt{\left\{\begin{array}{l}[R^2{}_i * (n-m-1)/(1-R^2{}_i) * (m)]/ \\ [R^2{}_m * (n-m-1)/(1-R^2{}_m) * (m)]\end{array}\right\}^2} \quad (A10)$$

where K(r,f) is a coefficient used to check the adequacy of mathematical models in linear regression, and K(p,f) is a coefficient used to check the adequacy of mathematical models in non-linear regression.

The Fisher criterion is important because in addition to its significance in the regression equation as a whole, this evaluation is necessary to lighten the burden of the model by removing factors that do not have a significant impact on the outcome.

The following conditions must be met for a model to be accepted: p value < 0.05 and tr > tm.

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