Real GDP Reliance of the Top-Three Oil Producing Countries (U.S.A., Saudi Arabia, Iraq) to Oil-Production: A Test for Linearity

Simon Philip M. Alejandrino (Sy)

Huy Bao (Kai) Nguyen Dam

December 09, 2022

Abstract

The Real Gross Domestic Product (GDP) has been a diverse accumulation of nation's wealth and a measure of economic efficiency. In a nation's GDP, oil is major contributor that accounts to approximately three percent (3%). This paper presents a simple macroeconomic model of the reliance of the real GDP of the top three oil producing countries – the United States of America (U.S.A.), Saudi Arabia, and Iraq. The model incorporates three independent variables namely average oil market price, field production of crude oil, and real inflation rate. There has been a strong existing linear correlation between oil production and real GDP with at least eighty percent of the data fits the linear line. The analysis suggests that real GDP of a nation has been always largely dependent to oil production.

Keywords: *Real GDP, Oil Production, Oil Market Price, Field Production of Oil, Real Inflation Rate, Linear Correlation*

I. Introduction

"To what extent do the top three (3) oil producer countries rely on their respective Real GDP on oil production?" One of the most significant commodities in the world - oil contributes around 3% of each country's gross domestic product (GDP) (Investopedia, 2022). Petroleum products are used in a wide range of items, including aspirin, textiles, solar panels, plastics, chemicals, and personal protective equipment. Little do we care about the prices of oil but it exists in almost every aspect of our daily lives, influencing our decision-making process without an obvious appearance. The low-price elasticity of oil consumption may eventually shift because of a worldwide drive toward sustainability (World Economic Forum, 2022). However, even if the energy shift picks up pace, it's critical to comprehend how supply and demand dynamics affect the price of oil and, by extension, the overall economy. Therefore, the main purpose of this paper is to test whether the market oil prices of distinct types of oils in the top three oil producer countries – the United States of America (U.S.A.), Saudi Arabia and Iraq – have a linear correlation with the real GDP growth of these countries via three dependent variables namely average oil market price, field production of crude oil, and real inflation rate. The scope of the study would include the strength of the linear correlation and explain how oil and oil-related products have been a major pivotal point of a nation's GDP.

II. Background

Since 1964, over 60 years ago, oil has been and continues to be the most important primary fuel. Absolute global oil consumption has been growing at a rate of 6 percent per year since records began being kept in 1870, 1.2 percent per year since 1973, when oil's share of global primary energy peaked, and 1.6 percent per year over the past decade. However, its market share in the

primary energy mixes across the globe has declined from 50% in 1973 to 33% in 2019 and is expected to continue falling (Energy Musings, 2021).

It is notoriously difficult to determine key parts of aggregate demand and supply schedules, such as price or income elasticities affecting gross domestic product (GDP), let alone make long-term predictions about oil prices and production. One more difficulty in modeling the market is that it can appear extremely cartelized at times and yet populated by a big flock of price takers and black markets (Erker & Ruhl, 2021).

The oil market has been fluctuating due to the non-expectancy of wars, financial crises, and paradoxically health concerns. Over the decades, the oil intensity due to increased efficiency in oil consumption. At the height of oil intensity in 1973, the global consumption was under one barrel of oil to generate a GDP worth a thousand dollars. Over the 35 years, the amount of oil required to produce $1000 of global GDP (0.43 barrels in 2019) has decreased by less than 0.01% every year (Rao & Wilkes, 2021). To assess the accuracy of this linear approximation, regressions were performed on overlapping windows of data with a span of 30 years (1991 to 2021) on three of the major oil-producing countries – namely the United States of America (U.S.A.), Saudi Arabia, and Iraq.

The pattern by which this progress has been achieved is studied by Columbia University's Center on Global Energy and Policy. Since 1984, oil intensity has decreased annually at a nearly perfect linear rate, with annual decreases in oil users per dollar of global GDP. Oil prices have been steadily declining over the past 35 years, despite the impact of wars, revolutions, economic booms and busts, OPEC successes and failures, and every other major event on the oil market (Chatzky & Siripurapu, 2022)

Over time, the global oil market shifted from being supply-constrained to being demand-constrained, which is reflected in the trend. First, oil intensity falls at a rate that is less than the growth of global GDP, allowing oil consumption to increase. Given its linear functional form, the rate of intensity drop will eventually outstrip global GDP growth, at which oil consumption will have reached its maximum and begin to decline (Abada *et al.*, 2017). The energy transition has not yet had much effect, but relative price adjustments might halt the trend by rearranging the degree of substitutability inherent in the capital stock. This means that a country's GDP that is most reliable for oil production will take a shock from the sudden transition and may cause a sudden financial crisis.

III. Methodology

Using Microsoft Excel, a Regression Analysis is run on the data. In checking the reliability of the data, a t-test, p-value test and F-test is used. In terms of t-test, the test is statistically significant if the t-value falls within the critical values. The same for p-value test, the test is statistically significant if the p-value is smaller than the chosen level of significance which is established at 5%. While in terms of F-test, the *F-value* will be compared to the corresponding F-critical value from the F-table based on the numerator of n and the numerator of n – (k + 1) with n being the number of observations and k being the number of independent variables; this means that test is significant if it is larger than the critical value. Further, the adjusted r-square value, the Coefficient of Determination, tells how many points fall on the regression line. The closer to 1, the better the regression line fits the data. The residuals show how far away the actual data points are from the predicted data points while using the population regression model that's defined:

$$Population\ Regression\ Model: y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$$

$y_i = Real\ GDP\ (current\ US\$)$

$B_0 = y - intercept$

$x_1 = Field\ Production\ of\ Crude\ Oil\ (Thousand\ Barrels\ Per\ Day)$

$x_2 = Average\ Market\ Price\ of\ WTI/OPEC\ Crude\ Oil\ (\$/barrel)$

$x_3 = Inflation, Consumer\ Prices\ (\%\ Annual)$

IV. Data

The data were collected for the three independent variables which are average oil market price, field production of crude oil, and real inflation rate. Further, the dependent variable, real gross domestic product (GDP), were in the time frame of year 1991 to 2021; this accounts to a span of thirty years.

The average oil market price differs based on the kind of the crude oil existing on the market – the three different types of oil represent each country. For the United States of America (U.S.A.), the collected data was from West Texas Intermediate (WTI) crude oil prices while Saudi Arabia and Iraq, as members of the Organization of the Petroleum Exporting Countries (OPEC), were collected relatively to the OPEC's oil market price. The data was organized in the units of U.S. dollars per barrel. The data were retrieved from Statista.com – *"a website that provides statistical data on many topics including media, business, politics, society, technology, and education. Sources include market reports, opinion research institutions, trade publications, scientific journals, and government agencies."* The specific web address is found on the Excel file or at the works cited section of this paper.

In terms of the field production of crude oil, the collected data were the quantities each country produces every day and the averages per year with units as thousand barrels per day. The data were retrieved from the US Energy Information Administration – *"an agency of the U.S. Federal Statistical System responsible for collecting, analyzing, and disseminating energy*

information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA programs cover data on coal, petroleum, natural gas, electric, renewable and nuclear energy." The specific web address is found on the Excel file or at the works cited section of this paper.

For the real interest rate, the data collected were on consumer prices annually for each country. The unit for this data is in percentage (%) and was retrieved from The World Bank Open Data - *"an analysis and visualization tool that contains collections of time series data on a variety of topics."* The specific web address is found on the Excel file or at the works cited section of this paper.

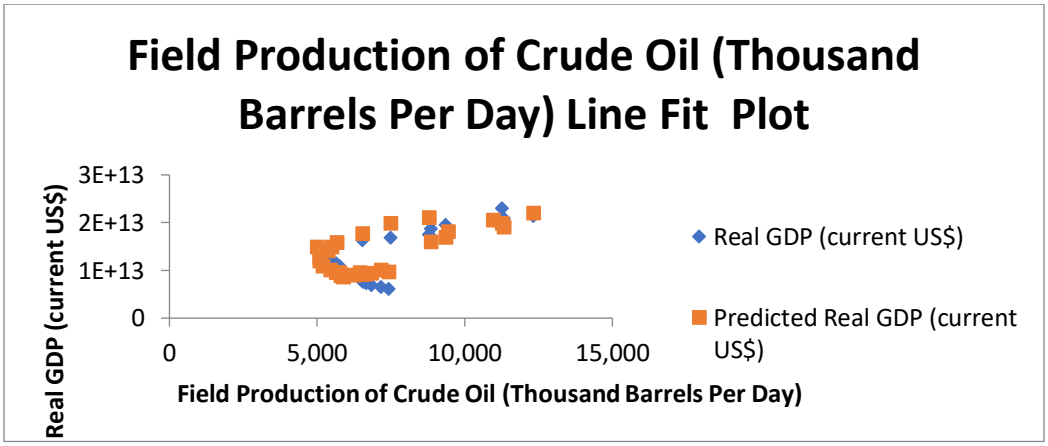

Figure 1. Field Production of Crude Oil (Thousand Barrels Per Day) Line Fit Plot of the United States of America.

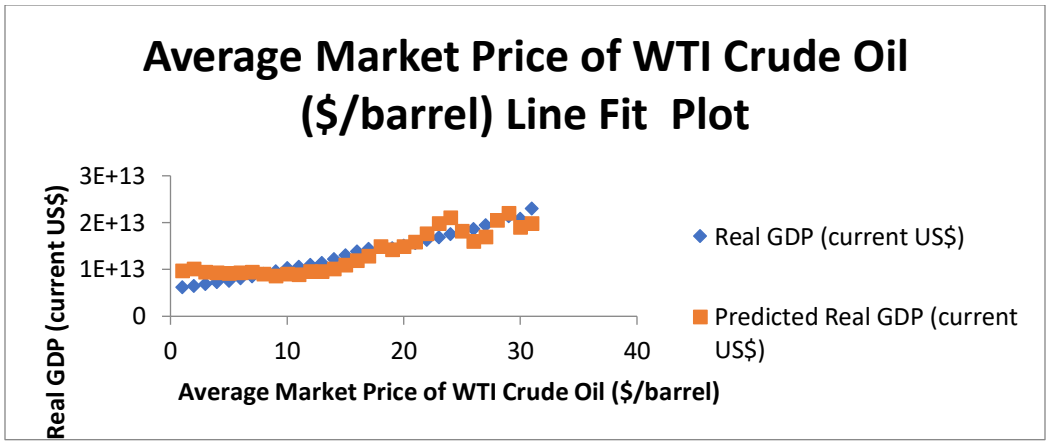

Figure 2. Average Market Price of WTI Crude Oil ($/ Barrel) Line Fit Plot of the United States of America.

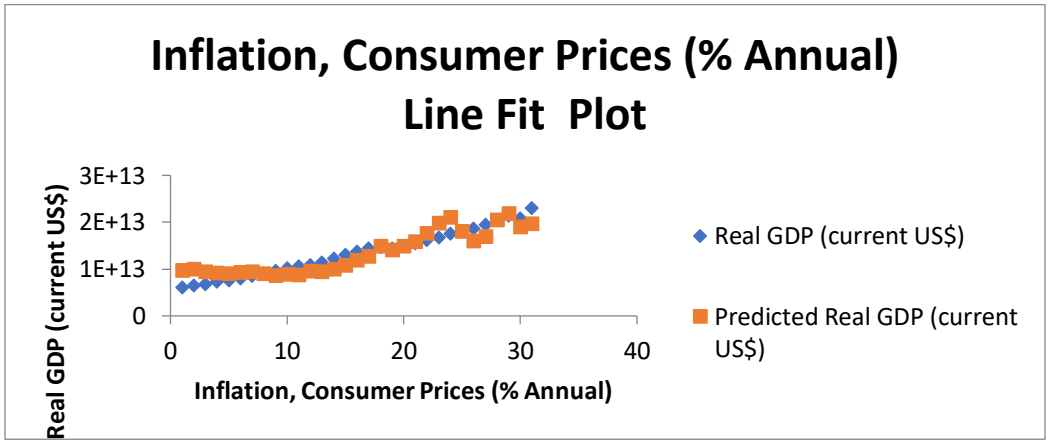

Figure 3. Inflation, Consumer Prices (% Annual) Line Fit Plot of the United States of America.

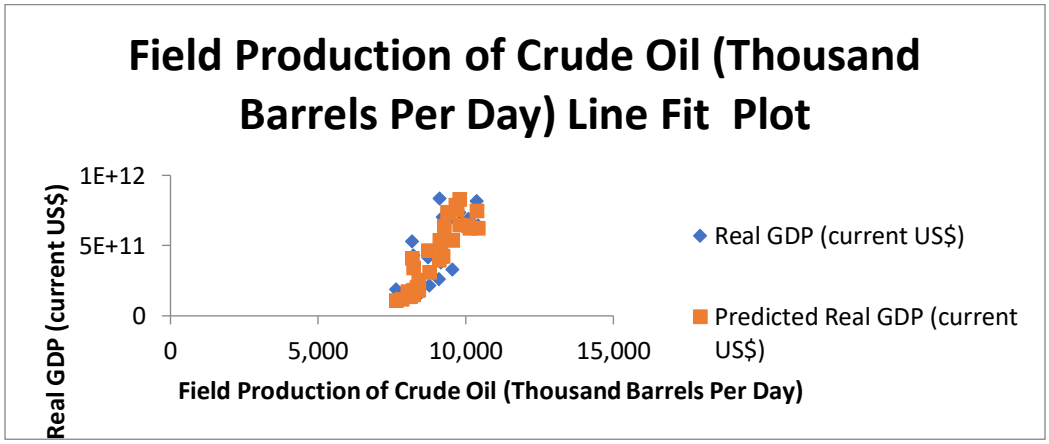

Figure 4. Field Production of Crude Oil (Thousand Barrels Per Day) Line Fit Plot of Saudi Arabia.

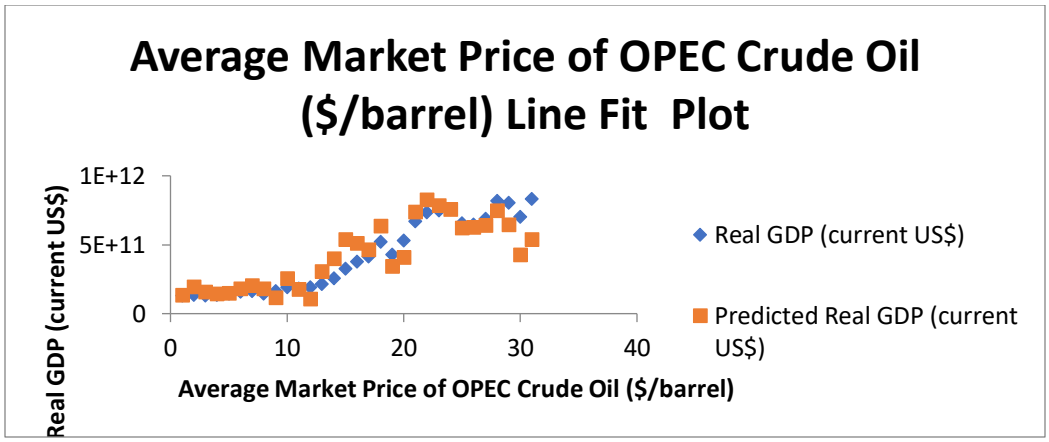

Figure 5. Average Market Price of WTI Crude Oil ($/ Barrel) Line Fit Plot of the Saudi Arabia.

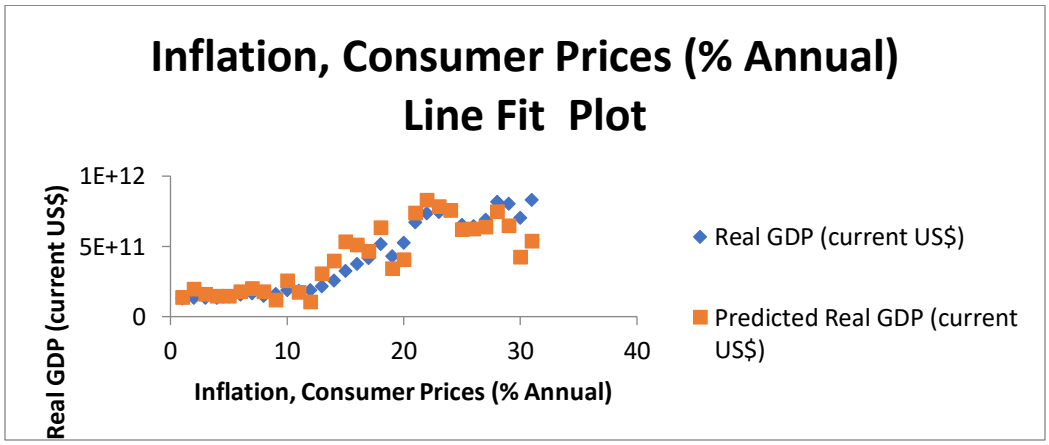

Figure 6. Inflation, Consumer Prices (% Annual) Line Fit Plot of Saudi Arabia.

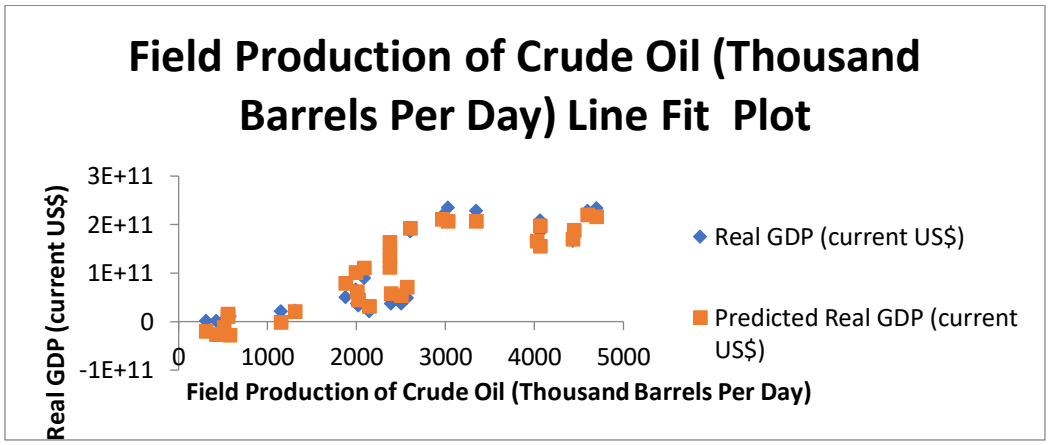

Figure 7. Field Production of Crude Oil (Thousand Barrels Per Day) Line Fit Plot of Iraq.

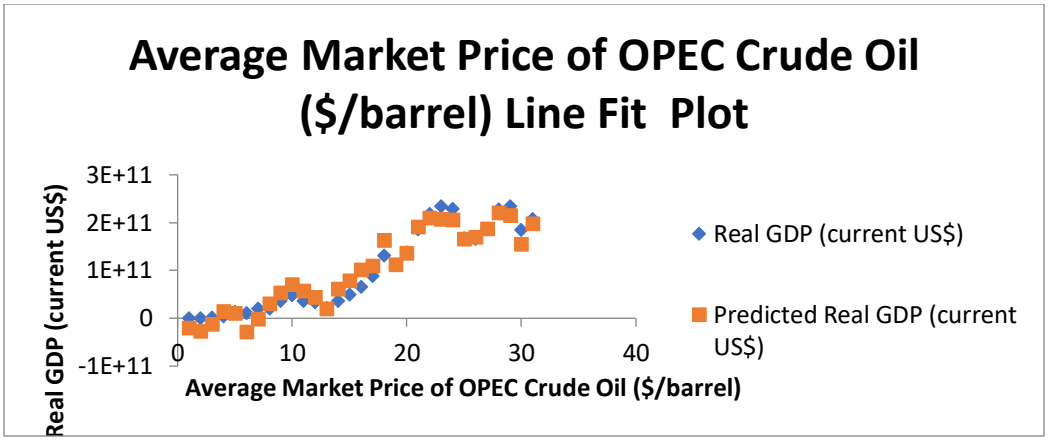

Figure 8. Average Market Price of WTI Crude Oil ($/ Barrel) Line Fit Plot of Iraq.

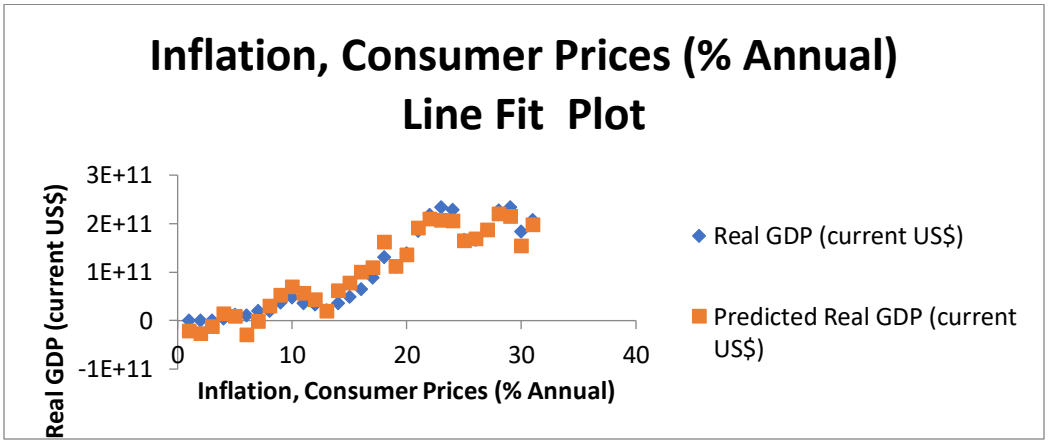

Figure 9. Inflation, Consumer Prices (% Annual) Line Fit Plot of Iraq.

V. Results

After running regression tests on the 3 countries, we receive 3 separate results about their models and we will interpret the results independently.

1. USA

Key features of the result:

- Adjusted R square/Coefficient of determination: 0.819403888
- Overall F-test: 46.37217754
- Coefficient of Field Production of Crude Oil: 1400121744.13116
- Coefficient of Average Market Price of WTI Crude Oil: 107830428538.972

- Coefficient of Real Inflation Rate: -650464440178.504
- t* for Field Production of Crude Oil: 7.57943735786356
- t* for Average Market Price of WTI Crude Oil: 7.89867454438469
- t* for Real Inflation Rate: -1.81832924422823
- p-value for Field Production of Crude Oil: 3.74599E-08
- p-value for Average Market Price of WTI Crude Oil: 1.71841E-08
- p-value for Real Inflation Rate: 0.080124956

Interpretation:

- The results for USA meet with our expectation. Considering the coefficient of determination of 0.82 in the possible range of 0 to 1, our model fits evidently well.
- We expect the coefficient of Field Production of Crude Oil to be positive because the higher the quantity of oil being produced, the higher our real GDP. The result matches our expectation.
- We expect the coefficient of Average Market Price of WTI Crude Oil to be positive because the more expensive the price, the more profits we get (assuming production costs stay the same) and thus, the higher our real GDP. The result matches our expectation.
- We expect the coefficient of Real Inflation Rate to be negative because the higher the real inflation rate, the lower the real GDP compared to the nominal GDP. The result matches our expectation.
- Overall, the independent variables explain the movements in our dependent variable quite well based on the results we got from the regression tests. Our model fits well.

2. Saudi Arabia

Key features of the result:

- Adjusted R square/Coefficient of determination: 0.80578868
- Overall F-test: 42.49030454
- Coefficient of Field Production of Crude Oil: 162396524.6
- Coefficient of Average Market Price of OPEC Crude Oil: 4506679570
- Coefficient of Real Inflation Rate: -5190975902
- t* for Field Production of Crude Oil: 4.635778444
- t* for Average Market Price of OPEC Crude Oil: 4.170268365
- t* for Real Inflation Rate: -0.510095874
- p-value for Field Production of Crude Oil: 8.10552E-05
- p-value for Average Market Price of OPEC Crude Oil: 0.000281675
- p-value for Real Inflation Rate: 0.614129184

Interpretation:

- The results for Saudi Arabia meet with our expectation. Considering the coefficient of determination of 0.81 in the possible range of 0 to 1, our model fits evidently well.
- We expect the coefficient of Field Production of Crude Oil to be positive because the higher the quantity of oil being produced, the higher our real GDP. The result matches our expectation.
- We expect the coefficient of Average Market Price of OPEC Crude Oil to be positive because the more expensive the price, the more profits we get (assuming production costs stay the same) and thus, the higher our real GDP. The result matches our expectation.
- We expect the coefficient of Real Inflation Rate to be negative because the higher the real inflation rate, the lower the real GDP compared to the nominal GDP. The result matches our expectation.

- Overall, the independent variables explain the movements in our dependent variable quite well based on the results we got from the regression tests. Our model fits well.

3. Iraq

Key features of the result:

- Adjusted R square/Coefficient of determination: 0.941870917
- Overall F-test: 163.0309269
- Coefficient of Field Production of Crude Oil: 42883765.16
- Coefficient of Average Market Price of OPEC Crude Oil: 1496217386
- Coefficient of Real Inflation Rate: 109381635.6
- t* for Field Production of Crude Oil: 11.48464465
- t* for Average Market Price of OPEC Crude Oil: 10.27738383
- t* for Real Inflation Rate: 2.54400358
- p-value for Field Production of Crude Oil: 6.72989E-12
- p-value for Average Market Price of OPEC Crude Oil: 7.86863E-11
- p-value for Real Inflation Rate: 0.01699378

Interpretation:

- The results for Iraq meet with our expectation. Considering the coefficient of determination of 0.94 in the possible range of 0 to 1, our model fits evidently well.
- We expect the coefficient of Field Production of Crude Oil to be positive because the higher the quantity of oil being produced, the higher our real GDP. The result matches our expectation.

- We expect the coefficient of Average Market Price of OPEC Crude Oil to be positive because the more expensive the price, the more profits we get (assuming production costs stay the same) and thus, the higher our real GDP. The result matches our expectation.
- We expect the coefficient of Real Inflation Rate to be negative because the higher the real inflation rate, the lower the real GDP compared to the nominal GDP. The result does not match our expectation.
- Overall, the independent variables explain the movements in our dependent variable quite well based on the results we got from the regression tests. Our model fits well.

Next, we will run statistical hypothesis tests on the coefficients via t statistics, p-value, and F-test for the global fit of the model. All of this hypothesis tests are conducted with a significance level of 5% and the null hypothesis are the coefficients equating to zero.

After running the t statistics hypothesis tests, we reject the null hypothesis of B1 and B2; we do not reject the null hypothesis of B3 for USA. We reject the null hypothesis of B1 and B2; we do not reject the null hypothesis of B3 for Saudi Arabia. We reject the null hypothesis of all the coefficients for Iraq. The same results apply for the p-value hypothesis tests (because t statistics and p-value are just different approaches, their results are basically the same.) These results mean that for USA and Saudi Arabia, the variables B1 and B2 have correlations to the dependent variable while the variable B3 has no correlation to the dependent variable. However, for Iraq, all of independent variables have correlations to the dependent variable. In other words, there is not enough evidence to conclude that Real Inflation Rate has an effect on real GDP in USA and Saudi Arabia; while there is enough evidence to conclude that Real Inflation Rate has an effect on real

GDP in Iraq. There is also enough evidence to conclude that both Field Production of Crude Oil and Average Market Price of WTI/OPEC Crude Oil have an effect on real GDP in 3 countries.

After running F-tests on the global fit of the model, we reject the null hypothesis for all 3 countries. This result indicates that our linear regression model provides a better fit to the data than a model that contains no independent variables. In other words, there is enough evidence to conclude that the data fits our model well.

Finally, we will run a correlation test between the independent variables to check for multicollinearity problem. There are a few noticeable multicollinearities. For USA, we did not find any noticeable multicollinearities. For Saudi Arabia, the Pearson Coefficient of Field Production of Crude Oil and Average Market Price of OPEC Crude Oil is 0.61; the Pearson Coefficient of Average Market Price of OPEC Crude Oil and Real Inflation Rate is 0.54. For Iraq, the Pearson Coefficient of Field Production of Crude Oil and Average Market Price of OPEC Crude Oil is 0.52; the Pearson Coefficient of Field Production of Crude Oil and Real Inflation Rate is -0.58.

VI. Conclusion

Oil had been a market that's tough to model. It shows signs of systematic structural alteration and reconfiguration, much like the global economy and energy markets. It's a market where the real gross domestic product of influential nations had depended on. The patterns into the reliance of the real GDP to the oil-production make up a coherent story, and it is through such narratives that an insight from the future is gained.

With the three independent variables, which are field production, oil market price, and higher inflation rate, a regression analysis was run through Excel to find their respective relationship with real GDP relatively with each country – naming USA, Saudi Arabia, and Iraq. Afterwards, testing of hypothesis using T-test, p-value test, and F-test were manually run to

examine the fit of the model with the data. The results answer the question on to what extent what extent do the top three (3) oil producer countries rely on their respective Real GDP on oil production

The regression analysis shows the respective fit of the regression model for each country – 82% for USA, 81% for Saudi Arabia, and 92% for Iraq. This means that Iraq has the best fit of the regression model but this doesn't conclude that the other two countries didn't fit the regression model as anything higher than 70% is known as good fit. Further, all the countries showed the expected relationship of each of the independent variable to the dependent variable. The results showed that the coefficients of the oil field production and market price are positive while the coefficient of real inflation rate is negative. This means that the higher the oil field production and market price, the higher the real GDP would be, while the higher the real inflation rate, the lower the real GDP would be.

After running T-test, p-test, and F-test, the results are the same for T-test and p-test but F-test showed a unique one. For the T-test and p-test, it showed as that the USA and Saudi Arabia's oil field production and market price has a correlation to the real GDP while the real inflation rate has no correlation at all to the real GDP. On the other hand, both tests showed that Iraq's oil field production, oil market price, and real inflation rate has a correlation with GDP. Thus, it can be concluded that oil field production and market price have correlation with GDP but it is insufficiently evident with real inflation rate. In running the F-test, it resulted to all the three countries respective independent variables data being correlated to the real GDP. This result indicates that our linear regression model provides a better fit to the data than a model that contains no independent variable. Therefore, there is sufficient evidence to conclude that the data fits our model well.

Subsequently, a correlation test between the independent variables was run to check for multicollinearity problems. For USA, we did not find any noticeable multicollinearities. For Saudi Arabia, the Pearson Coefficient of Field Production of Crude Oil and Average Market Price of OPEC Crude Oil is 0.61; the Pearson Coefficient of Average Market Price of OPEC Crude Oil and Real Inflation Rate is 0.54. For Iraq, the Pearson Coefficient of Field Production of Crude Oil and Average Market Price of OPEC Crude Oil is 0.52; the Pearson Coefficient of Field Production of Crude Oil and Real Inflation Rate is -0.58.

With this study and its results, it shows largely and deeply dependent influential nations' real GDP to oil production; this shows how oil production will impact the nation's future as may suddenly experience a financial crisis or a slow deterioration of the GDP growth. Oil-to-Energy transition is a famous banner to fight against pollution which may affect the consumption of oil. The world revolves around natural resources – oil, coal, gold, silver, aluminum, and many other – and the nation's wealth relies on them. The transformation of technology has been a withstanding effort in reducing the consumption of natural resources to reduce the footprints of pollution, and thus, protecting our environment in which we live in.

In effort to improve this paper, a test on different independent variables could be done (e.g., energy-to-fuel transformation, oil intensity, oil imports and exports). The model can be also altered to produce a different point of view towards the research question. Further, the tests done on this paper can be changed to provide better sufficient evidences to prove and answer the research question.

Works Cited

Abada, I., Ehrenmann, A., & Smeers, Y. (2017, June 2). Modeling gas markets with endogenous long-term contracts. Operations Research. Retrieved December 9, 2022, from https://pubsonline.informs.org/doi/abs/10.1287/opre.2017.1599

EIA. (2022). Natural gas and Petroleum. EIA. Retrieved December 9, 2022, from https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WCRFPUS2&f=WSaudi+Arabia%3A

Energy Musings. (2021, July 6). Prices Climbing Despite Push For Restrictions. PPHB. Retrieved December 9, 2022, from https://www.pphb.com/musing-from-the-oilpatch/energy-musings-july-6-2021-hpw4d

The Investopedia. (2022, August 19). What percentage of the global economy is the oil and gas drilling sector?. Investopedia. Retrieved December 9, 2022, from https://www.investopedia.com/ask/answers/030915/what-percentage-global-economy-comprised-oil-gas-drilling-sector.asp

Rao, S., & Wilkes, T. (2021, October 21). Why today's economy can handle oil at $100 a barrel or higher. Reuters. Retrieved December 9, 2022, from https://www.reuters.com/business/energy/why-todays-economy-can-handle-oil-100-barrel-or-higher-2021-10-21/

Siripurapu, A., & Chatzky, A. (2022, March 9). OPEC in a Changing World. Council on Foreign Relations. Retrieved December 9, 2022, from https://www.cfr.org/backgrounder/opec-changing-world

Statista. (2022, November 15). OPEC crude oil price statistics annually 1960-2022. Statista. Retrieved December 9, 2022, from https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

Statista. (2022, November 15). West texas intermediate oil price annually 1976-2022. Statista. Retrieved December 9, 2022, from https://www.statista.com/statistics/266659/west-texas-intermediate-oil-prices/

Titus, E., & Ruhl, C. (2021, September 9). Oil Intensity: The Curiously Steady Decline of Oil in GDP. Columbia University. Retrieved December 9, 2022, from https://www.energypolicy.columbia.edu/research/report/oil-intensity-curiously-steady-decline-oil-gdp

World Bank. (2022). GDP (current US$). World Bank: Open Data. Retrieved December 9, 2022, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

World Bank. (2022). Inflation, consumer prices (annual %) - saudi arabia. World Bank: Open Data. Retrieved December 9, 2022, from https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=SA

World Economic Forum. (2022, February 9). Why do oil prices matter to the global economy? an expert explains. World Economic Forum. Retrieved December 9, 2022, from https://www.weforum.org/agenda/2022/02/why-oil-prices-matter-to-global-economy-expert-explains/