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Modeling the Relationship Between Crude Oil Production, Deliveries To Refineries, And Distribution in the United States

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ABSTRACT
Crude oil is a vital resource that facilitates the delivery of commodities to ultimate customers and is also essential to the sustainability of the economy. This study's major objective is to investigate the connection between crude oil production, refinery deliveries, and distribution in the United States. The secondary data used in this analysis was collected between 2000 and 2022 by the U.S. Energy Information Administration. The applied unit root test indicates that all variables of interest become stable after the first difference, suggesting the application of additional econometric models. The use of the Johansen cointegration indicates a long-term relationship between crude oil productions, deliveries to refineries, and distribution to final consumers in the United States. The correlation analysis reveals a positive and significant positive association between crude oil production and shipments. The impulse response demonstrates that the response of crude oil production to the shocks of crude oil distributions is positive but the response of deliveries to the shocks of distribution to ultimate customers is negative. Thus, the government of the United States must grow the number of refineries in the country by creating more favorable conditions for the participation of private enterprises to ensure sustained high crude oil output and delivery to final customers.
Keywords: Crude oil, Unit root test, Johansen Cointegration, Impulse response function, Correlation analysis

1. INTRODUCTION

The petroleum refining sector in the United States is the largest and most advanced in the world as of 2019. With the elimination of the U.S. Crude Oil Export Ban in December 2015, there are no longer any restrictions on international trade in this sector, and the American market has been completely integrated into the global market for refined goods. Around 19% of the world's 98.7 million barrels per day (MMBD) oil refining capacity was supplied by the United States in 2017, according to OECD/IEA (2018). By 2022, the domestic energy capacity in the United States is predicted to expand by an additional 0.2 MMBD, according to predictions from the International Energy Agency (OECD/IEA, 2017a). However, the U.S. petroleum refining business now faces additional difficulties due to changing geographic trends in the growth of refined petroleum product demand, changes in the addition of processing capacity, and the growing complexity of refineries globally (Zavaleta et al., 2015). The world's refining capacity increased by 17 MMBD between 2000 and 2017, with 65% of the growth taking place in Asia and 15% in the Middle East (Gresh et al.,2017). As a result of the projected increase in worldwide refining capacity from 2017 levels of 7.7 MMBD, a similar pattern is envisaged from now until 2023 (OECD/IEA, 2018). Between 2017 and 2023, the Middle East, China, and India are predicted to account

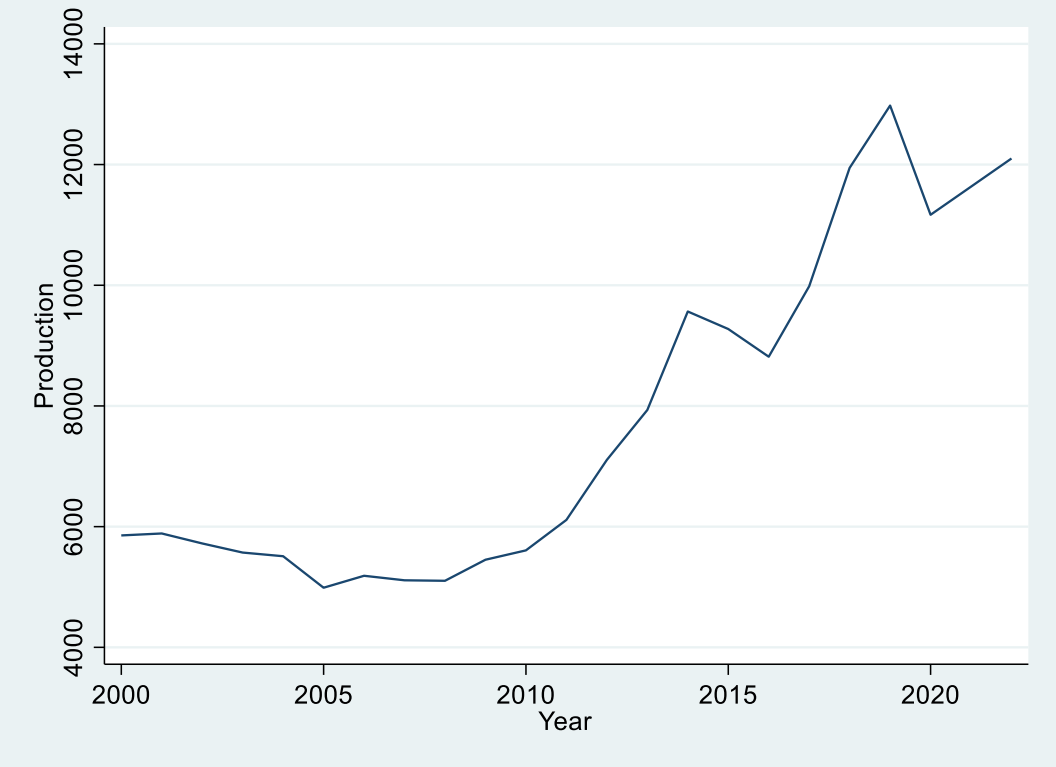
for more than half of the capacity expansions (including sizeable projects in Kuwait and Saudi Arabia). The latter investments are driven by the robust economic expansion that is raising standards of living and raising demand for transportation fuel in many non-OECD nations.

The newly implemented fuel regulations in Asia (Lofting et al., 2018) and China's ambition to become a significant supplier of refined petroleum products to South East Asian countries both had a part in the capacity expansion. Demand is anticipated to decline in the United States and Europe in contrast to anticipated gains in China, South America, and Africa. Although they presently account for 81% of the world's primary energy consumption, fossil fuels will only account for 79% and 75% of it by 2040, respectively, under the World Energy Outlook's current policy scenario and new policies scenario (OECD/IEA, 2017b). According to the OECD/IEA (2018), the demand for fossil fuels is expected to climb from 99.9 MMBD in 2018 to 104.7 MMBD by 2023, with oil accounting for the majority of that increase. Although it was anticipated that refined products would make up about 85% of all liquid consumption, predictions indicate a jump in product demand of 4.8 MMBD between 2017 and 2023 (OECD/IEA, 2018). With the commencement of the shale oil revolution in 2005, the United States has drastically boosted its exports of refined petroleum products. In 2008, the US began to net export commodities that were refined. 88% of the world's total production of gasoline, diesel, jet fuel, kerosene, and residual fuel oil was produced by U.S. refineries in 2017 (EIA, 2018a). The most significant product for refiners on the domestic market is petrol, which accounts for 51% of the overall output of refined products in any given year. Petrol use has a big impact on refiners' profits. Although fuel demand in the United States varies with cyclical changes in economic activity, a long-term historical tendency of rising consumption can be seen.

Predictions state that this trend will soon reverse, in part due to new automobiles' improved fuel economy and the gradually rising share of hybrid and electric vehicles in the U.S. fleet of vehicles. This research suggests that refinery output volumes will maintain their long-term growth trend even though it is projected that the total demand for refined goods in the United States will fall over the next 20 years. US refiners will need to adapt to these changes as well as the observed moves in the world's key demand and supply centres. Also, businesses must look for ways to increase sales in their current export markets and/or find new markets for their products. The American Petroleum Institute estimates that the oil and natural gas sector in the United States supports nine million jobs and accounts for 7% of the country's GDP (API, 2015). The oil and natural gas sectors will contribute 8% of the U.S. GDP and 10.3 million jobs by 2021 (US Economy fact sheet, 2021).

The United States overcame Saudi Arabia and Russia to become the leading oil producer in 2018, generating 15% of all crude oil worldwide (US Economy fact sheet, 2021). Daily output in the Gulf of Mexico's offshore federal zone came from Texas at 5.07 million barrels (806,000 m3), North Dakota at 1.42 million barrels (226,000 m3), and New Mexico at 0.90 million barrels (143,000 m3). In 2019 Texas produced the most oil in the country. The US's top five oil-producing states in 2020 were Texas (43%), North Dakota (10.4%), New Mexico (9.2%), Oklahoma (4.1%), and Colorado (4.0%) (EIA, 2021).

The yearly crude oil production in the United States normally decreased between 1985 and 2008, but it grew almost every year from 2009 to 2019, reaching its highest level ever in 2019 (EIA, 2020). The COVID-19 pandemic had an impact on US crude oil production, which decreased from 2019 to 2020. Nevertheless, it increased from 2021 to 2022 as a result of US efforts to support European states during the Russian-Ukrainian War (World Bank, 2022, see Figure 1).



Source: U.S Energy Information Administration (2000-2022)

Production increased, especially in Texas, North Dakota, Oklahoma, New Mexico, and Colorado because of more affordable drilling technologies (EIA, 2020). In 2020 and 2021, U.S. crude oil output fell, primarily as a result of the COVID-19 pandemic's effects on the economy (EIA, 2022). As a result, this study tends to use a quantitative technique to examine the relationship between crude oil production, delivery to refineries, and distribution in the United States.

2. Literature review and hypothesis development

The first atmospheric distillation-based oil refinery in the United States began operating in 1862 (API, 2011), and the American car industry followed suit in the early 1890s. In 2018, the United States is home to the biggest and most sophisticated refining sector in the world. Since 1985, when there were 199 refineries in the country, the number of refineries has decreased steadily due to industry consolidation, from 199 in 1985 to 132 in 2019. Beginning in the 1980s, a significant number of refineries ceased operations, and plant closures were mostly brought on by changes in the market environment that increased the importance of economies of scale and refinery complexity. Regulations that are altered, such as pricing limits, tougher fuel requirements, and modifications to the supply or demand of local inputs, all have a part (Meyer and Taylor, 2018). Because of this, existing refineries typically process lower than 50,000 barrels per day and are smaller and less technologically advanced (Meyer and Taylor, 2018). In their examination of a discussion on how consolidations affect the cost of refined goods, Kendix and Walls (2010). Even though the last brand-new crude oil refinery was built in 1977, numerous companies invested a lot of money in new and existing technology and equipment to process crude oil distillation unit output more thoroughly and, as a result, enhance overall product production (EIA, 2018b). Due to investment and innovation, refineries have been able to "debottleneck" and increase the output of higher-yield products. The operational distillation capacity of U.S. crude oil was 18.8 MMBD in 2019 (EIA, 2019a).

The effects of crude oil output by OPEC and non-OPEC countries on global oil prices and economies were examined by Ronald and Joaquin (2015). They employed the SVAR model and utilised data on

crude oil production by OPEC and non-OPEC nations spanning from the first quarter of 1974 to the fourth quarter of 2012, along with the corresponding oil prices from the first quarter of 1974 to the first quarter of 2014, in order to ascertain whether the crude oil output of OPEC countries had a significant influence on the price of crude oil. They also looked into whether changes to non-OPEC nations' oil output would have affected OPEC nations' oil production and, in turn, the price of crude oil. Their research's findings revealed an antagonistic relationship between the rise in OPEC crude oil output between 1974 Q1 and 1996 Q4. They concluded that a coup d'état that took place in Iran from 1978 to 1979 and a war that broke out between Iran and Iraq in 1980 both affected the nation's ability to produce and export crude oil, resulting in a daily reduction in oil production of 2-2.5 million barrels for OPEC member Iran. They concluded that this was the reason why the price of crude oil rose from US $14 in 1978 to US $35 in 1981.

Crude oil dominates the commodities market, accounting for 40% or more of global energy use. Particularly oil-dependent economies worry about the oil price's unpredictability. The unpredictability's detrimental and disruptive effects on the economy could prevent future, sustained economic growth (Ebrahim et al. 2014; Su et al. 2021). Petroleum crises, such as the Arab oil embargo (1970), the Iran-Iraq war (1980), the first Gulf War (1990), the global financial crisis of 2008, and the current COVID-19 pandemic (2020), enhance the unpredictability of oil prices and significantly affect the economic growth of nations. As a financial reserve, haven, or form of economic insurance against escalating commodity instability, gold, on the other hand, provides these functions (Wang et al. 2021a, b).

Even though there are many uses for oil, the transportation sector consumes most of it globally, accounting for 30% of the overall demand. The transportation sector uses 20% of the energy used worldwide (Capuano, 2018). Haasz et al. (2018) talked about the potential for decarbonizing the transportation industry in the EU-28. They noted that while crude oil consumed 33% of all energy in the EU, it had a favourable impact on the transportation industry. According to Khan et al. (2022a), the use of oil as a fundamental material appears to be connected to all forms of transportation, including ships, planes, and automobiles, either directly or indirectly. The development of all forms of transportation could, however, result in an increase in the demand for crude oil. Additionally, it is expected that in 2045, with 109 million barrels per day, transportation fuels like petrol and diesel will be the most widely consumed goods (Nouni et al. 2021).

Sodeyfi and Katircioglu (2016) looked empirically at oil supplies to refineries, industrial value-added, and the Eurozone, the European Union, Latin America and the Caribbean, South Asia, and Sub-Saharan Africa. They demonstrated that there are global long-run relationships between industrial value-added, oil deliveries, and economic growth. The research demonstrates that while the sector has a favourable influence on oil, it has a long-term detrimental influence on actual income.

Therefore, the following hypotheses have been proposed based on the previous studies;

H1: Crude oil distribution and production have a positive relationship.

H2: Crude oil production, deliveries to refineries and distribution have long-run association.

3. DATA AND METHODOLOGY

3.1 Data

A quantitative research design was adopted for this study and secondary data collected from U.S Energy Information Administration from 2000 to 2022 was used for the analysis of this study. The variables of interest are crude oil production, deliveries to the refineries and distribution. The unit of measure is in Barrels.

3.2 Methodology

The method of analysis employed for this study is a quantitative approach which includes descriptive statistics (such as mean and standard deviation) as well as econometric models' approach like unit root test, Johansen cointegration and impulse response function as well as correlation analysis. This study adopts the concept of empirical study.

3.3 Model specification

The empirical models adopted for this study can generally be specified as;
Crude oil production = f (Crude oil deliveries to the refineries and distribution).
The dependent variable is crude oil production while the independent variables are Crude oil deliveries to the refineries and distribution. But the econometric models apply to this study treat all the variables as endogenous.

3.3.1 Unit root test

The presence of unit root suggests that the series is not stationary, which often led to erroneous findings if not rectified. The test is conducted to rectify the tendency of having erroneous results. The unit root test hypothesis is stated as follows:
H_0: there is an existence of a unit root vs. H_a: there is no unit root (the variable is stationary). The augmented dickey fuller (ADF) test can be presented mathematically as:

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \mu_t$$

Where, α is a constant, γ is the coefficient of process root, β_i coefficient in time tendency, p is the lag order and μ_t is the disturbance (error) term.

3.3.2 Johansen cointegration

An approach for evaluating the cointegration of integrated variables of the first and second order is the Johansen cointegration test. This test examines the significance of the cointegrating equation from the series. The trace and max eigenvalue tests are the two types of Johansen tests, and they serve as the foundation for any inference or conclusion. The results of these tests may differ slightly from those of other tests. The fact that all the variables are handled as endogenous variables should also be noted.

3.3.3 Impulse response function

In econometrics, an impulse response function (IRF) employs a graphical method to assess how a variable affects either the shock itself or another endogenous variable. IRF, in other terms, studies how one variable reacts to the shocks of another. For this study, EViews version 11.0 was used in computing the impulse response function.

3.4 Correlation analysis

This is a quantitative approach applied in this study to investigate the direction and strength of association between two variables. Pearson correlation was adopted in this research study and the correlation coefficient is denoted with r which falls between -1 and + 1 respectively. The t-test was used to test for the significance of the correlation using SPSS software version 26.

4. RESULT AND DISCUSSION

4.1 Results

This section presents the results of the analysis of this study.
Table 1: Descriptive statistics

	N	Mean	Std. Deviation
Production	23	7765.5652	2734.3333
Deliveries	23	3069.7391	124.2849
Distribution	23	2315.6522	2676.9344
Valid N (listwise)	23		

Source: Author's computation using SPSS software

Table 1 shows that the average crude oil production is about 7.8 Million Barrels during the period under review with a variability of about 2.7 Million Barrels. The deliveries to the refineries on average are about 3.1 Million Barrels with a variability of about 124 Thousand Barrels while the average crude oil distribution is about 2.3 Million Barrels with a variability of about 2.7 million barrels during the period under review.

Table 2: Unit root test

Differenced Variables	Test statistic	P-value	Order
Production	-3.87	0.0087	I (1)
Deliveries	-5.62	0.0002	I (1)
Distribution	-5.06	0.0006	I (1)

Source: Author's Computation using EViews software

Table 2 shows the result of the unit root test of the series (crude oil production, deliveries to the refineries and distribution) and we can see that all are statistically significant at the 5% level and become stationary after the first difference. Therefore, further econometric analysis can be performed.

Table 3: Johansen Cointegration

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.691628	37.77793	29.79707	0.0049
At most 1	0.419616	13.07254	15.49471	0.1122
At most 2	0.075439	1.647170	3.841466	0.1993

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Source: Author's Computation using EViews software

Table 3 shows that one of the cointegrating equation is statistically significant at a 5% level and this implies that there is the presence of cointegration among the variables of interest which suggests a long-run relationship between crude oil productions, deliveries to the refineries and distribution. This supported hypothesis 2.

Table 4: Correlation analysis

		Production	Deliveries	Distribution
Production	Pearson Correlation	1	-.265	.953**
	P-value		.222	.000
	N	23	23	23
Deliveries	Pearson Correlation	-.265	1	-.345
	P-value	.222		.107
	N	23	23	23
Distribution	Pearson Correlation	.953**	-.345	1
	P-value	.000	.107	
	N	23	23	23

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author's Computation using SPSS software

Table 4 shows the Pearson correlation analysis result and it shows that there is a strong positive and statistically significant relationship between crude oil production and distribution. This supported

hypothesis 1 and it suggests that the higher the crude oil production, the higher will be the distribution to the final consumers.

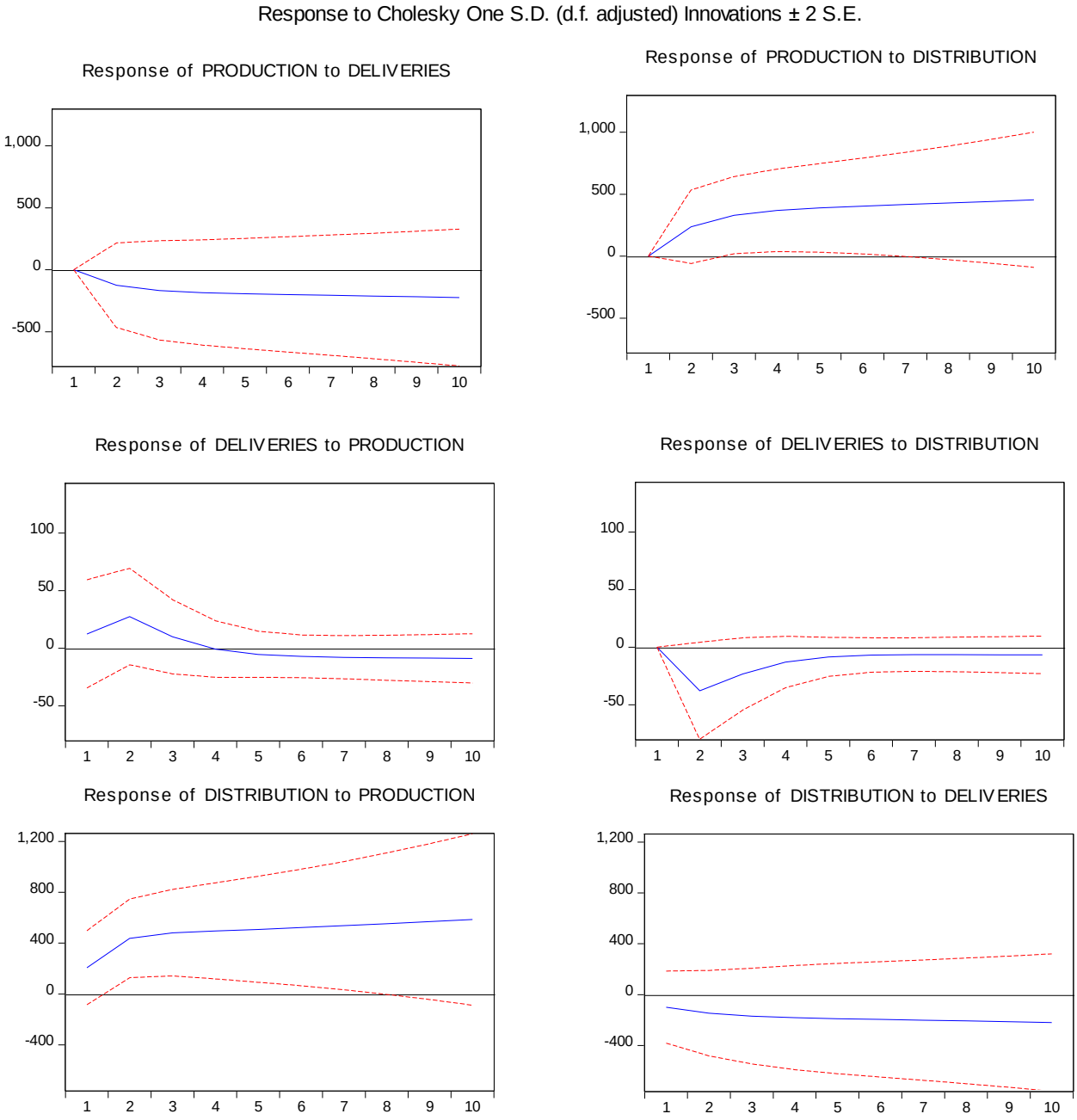


Figure 2: Impulse response function

The impulse response function for all endogenous variables is shown in Figure 2 as a blue line that is contained by the two red 95% confidence intervals. Additionally, the impulse response of crude oil production to the shocks of crude oil distributions falls between the two 95% confidence intervals that are above the zero line and indicates a positive response, which suggests that the more crude oil produced, the more distribution there will be to the final consumers of the US economies. It is interesting to note that while the line above zero reflects a positive response, the line below zero shows a negative response.

While the impulse response of the deliveries to the shocks of the distribution also falls between the two 95% confidence intervals and is also below the zero line, indicating a negative response, the impulse response of crude oil production to the shocks of deliveries to the refineries falls between the two 95% confidence intervals.

4.2 DISCUSSION OF FINDINGS

This section presents a discussion of the notable findings from the results of the analysis of this research work.

As shown in Figure 1, the US boosted its crude oil output from 2021 to 2022 to meet the demand and make it available in the US due to the strong demand for crude oil in Europe as a result of the Russia-Ukraine war, which led to supply shocks. The impulse response function for all endogenous variables is shown in Figure 2 as a blue line that is enclosed by the two red 95% confidence intervals. The impulse response of crude oil production to the shocks of crude oil distributions also shows a positive response and falls between the two 95% confidence intervals that are above the zero line, which suggests that the more crude oil produced, the more distribution there will be to the final consumers of the US economies.

Table 2 displays the outcomes of the unit root test for the series (crude oil production, shipments to the refineries, and distribution). As can be observed, every result is statistically significant at the 5% level and stabilises after the first difference, suggesting that more economic study can be done.

Table 3 demonstrates that one cointegrating equation is statistically significant at a 5% level, indicating the presence of cointegration among the series and indicating the existence of a long-term relationship between crude oil productions, deliveries to the refineries, and distribution to the final consumers in the United States. This finding is highly consistent with the work of Sodeyfi and Katircioglu (2016). This likewise supported hypothesis 2.

Also, table 4 displays the results of the Pearson correlation study, which demonstrates that the distribution and production of crude oil are positively and statistically related. This validated hypothesis 1, and it implies that the distribution of crude oil to American customers will increase in proportion to increased crude oil output.

5. CONCLUSION AND POLICY IMPLICATION.

Crude oil is a vital instrument to every country's economy, which is why it is so important to provide it for the necessary refining and distribution to consumers for the country's economic operations to advance. The purpose of this study is to look into the connections between crude oil distribution, refinery deliveries, and production in the US. According to the econometric model used in this study, there is a long-term correlation between crude oil production, deliveries to refineries, and distribution to final customers in the United States. The correlation analysis and impulse response function revealed that the distribution to final customers would increase in proportion to the level of crude oil output. In the meantime, a negative reaction was seen in how the deliveries responded to the shocks of the distribution to the final consumers. To attain sustainable high crude oil production and deliveries to the ultimate consumers, the US government must grow the number of refineries in the country by establishing more favorable conditions for the participation of private industries.

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