

RESEARCH ARTICLE

Sensitivity of Crude Oil Price Change to Major Global Factors and to Russian–Ukraine War Crisis

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Abstract: To assess the elasticity of crude oil price to global factors related to supply of crude oil and the US dollar exchange rate, the authors employed nonlinear models including flexible least squares, and maximum likelihood estimator, in addition to OLS regression mode; using yearly data from 1965 to 2021. The findings indicate change in oil prices due to 1% change in any of the explanatory variables, as follows: the effect of the US dollar depreciation rate, raise crude oil price/barrel by 71 US cents; and increase in OPEC production, decrease crude oil price by 82 US cents; a decrease in non-OPEC production, raise oil price by 4.78 US\$. These results imply that, if a ban imposed on Russian crude oil export, and no increase in OPEC production to compensate Russian oil loss in the international markets, global crude oil price expected to rise by 88 US\$ above its level before Russian–Ukraine crisis, meaning that crude oil price expected to rise at 160 US\$ pb^{①②}. However, if OPEC members increase their output level by 10 million barrels per day to compensate the Russian oil loss, then global crude oil price is expected to stay at 102 US\$ pb.

Keywords: OPEC, Crude oil price, Russian and Ukraine crisis

① Russia produces about 18% of non-OPEC production, and 12% of total world production in 2021.

② To compute the 88 US\$ value from estimated coefficient value, as Russia is non-OPEC member, we used the equation: $\{(Russian\ output) / [(non-OPEC\ output) * (0.01)]\} * 4.78\ US\$$.

1. Introduction

Frequent swings in crude oil prices in the past decade revealed that oil prices falling away from the control of

the major producers of OPEC group. Empirical research on this issue attributes the continued oil price rise since June 2020 to some factors including, an increase in demand, weather-related supply disturbances, and controlled

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production by OPEC and its partners (OPEC+). Oil prices have also been influenced by higher natural gas prices, which increased the demand for oil for heating and electricity generation purposes. A major factor that influenced oil demand rise in the third quarter of 2021 was the lift of covid-19 lockdown measures, especially in Europe. At the onset of the pandemic at the end of 2019, due to sudden drop in demand for crude oil, oil price dropped from above \$60 per barrel to about less than \$30 PB, before gradually rising by mid-2020 (Figure 1). However, higher volatility of oil price changes has been witnessed at the post-pandemic period, as indicated in Figure 2. Figure 3 reveals that the recovery of global oil demand, excluding China, was very sluggish, as the global demand in the 4th quarter of 2021 was about 3 percent below its pre-pandemic peak. The fastest recovery has been in China, where demand at the end of 2021 climbed above 10 percent to its pre-pandemic level. By mid-2021 production in the United States was affected by Hurricane Ida while OPEC and its partners, especially Angola, Kazakhstan, and Nigeria produced about 1 million barrels per day below their quota due to maintenance, according to data from the International Energy Agency. Due to persistent decline in production since August 2020, oil inventories continued to decline by just over 1 percent per month since August 2020, causing OECD industry inventories to decline around 4 percent below their five-year average in July 2021.

Another factor that attributes to change in global oil

prices is depreciation in the US dollar exchange rate. Novotny, 2012, showed that Brent crude oil prices are negatively correlated with the US dollar exchange rate depreciation. This implies that appreciation of the US dollar in the past few years may have contributed to the downfall of crude oil prices. This implies that, as crude oil is priced in the US dollar in the international markets, then part of oil export income loss caused by oil price fall, can be compensated partially by the rising dollar value.

In general, what makes crude oil markets volatility so fascinating, is that it's really a very interesting interplay of financial markets, supply and demand forces, the currency market, geopolitics and environmental factors^③. A distinctive feature of this current research is to assess the impact of all these factors on crude oil price change, under different estimation methods. More specifically, this paper contributes to the existing literature by assessing the sensitivity of crude oil price changes to major global factors related to supply of crude oil prices as well as other factors like US dollar exchange rate and sudden shocks in oil demand, to estimate the impact of the ongoing Russian–Ukraine war crisis on international crude oil price change, under different scenarios related to OPEC producers' reaction.

The remaining sections of the paper include the following. Section two includes a literature review of the most relevant research papers, section three highlights the research methodology, section four includes the analysis of the findings, and the final section concludes the study.

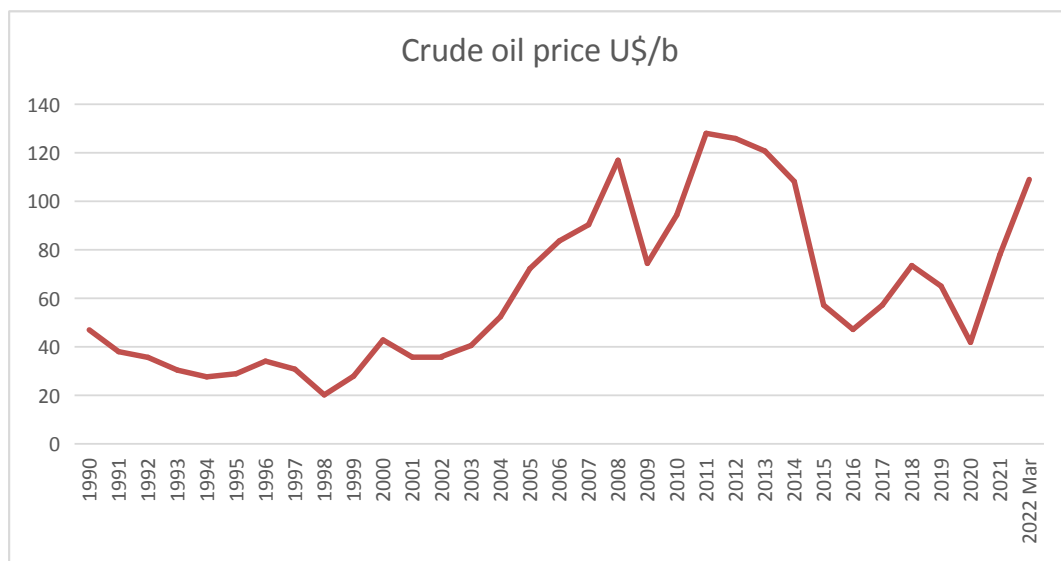


Figure 1. Historical crude oil price trend (1990 – March 2022).

③ Since global production of crude oil is dominated by a few major producers, tension with one of those nations can cause major problems. So if there's war or conflict in an oil-producing region, crude inventories could seem threatened, and that could ultimately alter the price of oil. Geopolitics has traditionally been a factor in the oil price shocks. This is exactly what the current paper is trying to capture.

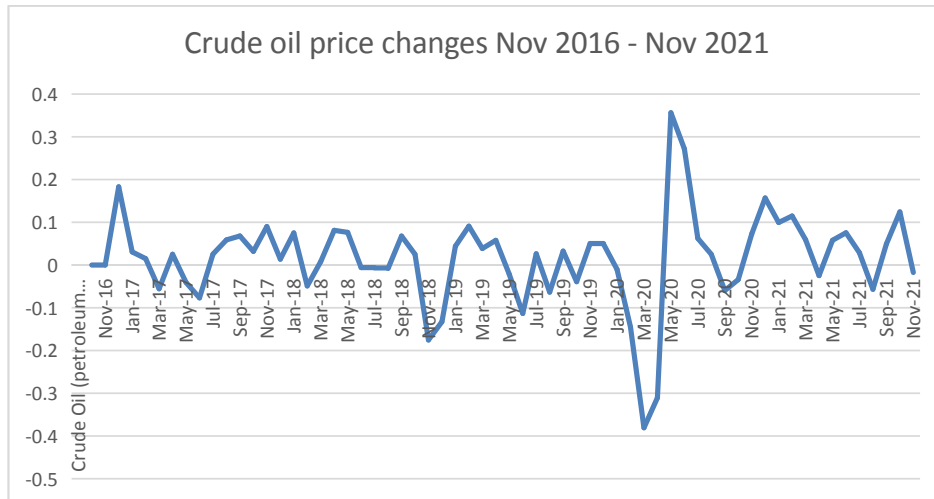


Figure 2. The behavior of crude oil price changes.

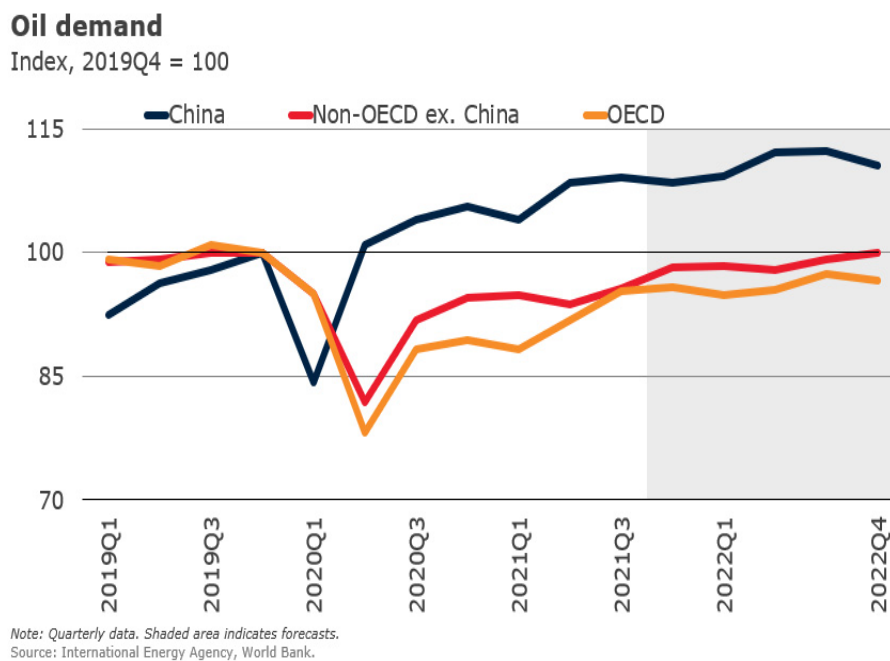


Figure 3. Demand for crude oil.

2. Literature Review

Since the oil crisis of 1974, research work in energy economics focused on the modeling aspects of supply shocks and quantifying their impact on the global economy.

Kilian ^[1] simulated and analyzed different types of shocks on crude oil markets to verify that different types of shocks have different duration and magnitude impact on crude oil prices. Wang et al. ^[2] constructed a transfer function noise model to assess the cyclical trend of the impact of different global shocks on crude oil prices. Coleman ^[3] simulated the impact of the effect of the Asian

financial crisis, the Kuwait invasion, and the oil worker strike in Venezuela, on crude oil prices, to conclude that significant shocks lead to significant change in oil prices. Fang et al. ^[4], investigates how explicit structural shocks that characterize the endogenous character of changes in oil prices affect three large newly industrialized large economies' stock-market returns. Liao et al. ^[5] used event analysis to indicate that the influence of natural disasters is less than that of social conflict and that strategic release of petroleum reserves can help ease price swings.

Among the early CGE models that assess the effects of crude oil shocks on economic growth using determinants

of supply and demand for crude oil to estimate the equilibrium price level^[6]. Then shortly later, a partial equilibrium modeling specification employed to predict crude oil prices for the period (1986 ~ 1991)^[7]. In a general equilibrium model framework, Kaufmann et al. (2004), estimates the influence of the Saudi government, as the largest producer in the OPEC cartel, on OPEC oil price behavior^[8]. Other models estimated the effect of short-run determinants of crude oil prices in OECD and non-OECD countries using, as explanatory variables, gross national income, exchange rates, technological progress, and demand for biofuel^[9,10]. Kaufmann et al. (2007) showed evidence of a non-linear association between refinery capacity utilization levels and oil prices^[11]. Using an optimization model, Huppmann and Holz (2009), indicate that Saudi Arabia plays a leading role among OPEC producers, gains oligopolistic profit while the rest of the OPEC cartel gains competitive profit^[12]. Research findings also indicate evidence of a common cyclical association between change in US oil production and change in global crude oil prices, but no evidence of common cycle features between change in OPEC production and global crude oil prices, implying that change in OPEC production influence crude oil price trend in the long term, but the short-term cyclical change of crude oil prices mainly guided by change in US crude oil production^[13]. On the US dollar exchange rate effect, indicated that the effect of the US dollar exchange rate on crude oil price, is significant only in the long term, but not effective in day-to-day short-term transactions^[14].

3. Methodology

As indicated in Figures 1 and 2, the global oil market witnessed in the second quarter of 2020 a remarkable shock due to global demand drop which requires the use of non-linear time-varying coefficient models, as well as non-normal distribution residual-based regression methods. Flexible least square (FLS) and the maximum likelihood method (MLE) methods are potential important candidates to capture dynamic changes of coefficients and residual non-normality requirements. The FLS estimations yield a range of coefficient values, high and low values reflecting the time path of coefficients estimates. More specifically, time-changing coefficients models can take the following form:

$$P_t = X_t B_t + \varphi_t E_t + e_t \quad \text{for } t = 1, 2, \dots, N \quad (1)$$

where p_t is a column vector of oil price at time t , X_t , and E_t , are explanatory independent variables, and e_t is a random residual error term. The explanatory variables in our specification include US dollar exchange rate as measured by US\$ price per gold oz; OPEC production; Non-OPEC

production; refining capacities; and E_t = adverse supply shock, approximated by an excess demand for crude oil, as measured by supply drop below demand level.

The FLS method developed by Kalaba and Tesfatsion (1989) determine the time paths of the coefficients based on the sum of dynamic squared residual errors, and the sum of squared residual errors as defined in the following^[15]:

$$\begin{aligned} C(\beta; \delta, N) &= \frac{1}{1-\delta} \left[\delta \sum_{t=1}^{N-1} (\beta_{t+1} - \beta_t)' \right. \\ &\quad \left. (\beta_{t+1} - \beta_t) + (1-\delta) \sum_{t=1}^N (p_t - Z_t' \beta_t)^2 \right] \\ &= \frac{1}{1-\delta} [\delta r_D^2(\beta; N) + (1-\delta) r_M^2(\beta; N)] \end{aligned}$$

where $Z_t = (X_t, E_t)$, $\beta = (\beta_1, \beta_2, \dots, \beta_N; \varphi)$ is the time-path of coefficient vectors, r_D^2 is the sum of squared dynamic residual errors, that reflect the difference in successive coefficient values, and r_M^2 is the sum of squared residual errors, and $\delta \in (0,1)$ is smoothness weight. The OLS extreme point occurs when $\delta = 1$, and equal weights apply when $\delta = 0.5$. The FLS solution is sensitive to the choice of the smoothness parameter.

4. Analysis

Data used in this analysis were collected from Index Mundi websites and from BP Statistical Review of World Energy^④. Variables include OPEC and non-OPEC crude oil production, global refineries capacity expansion, Brent oil price, and US\$ dollar price per gold, in addition to excess demand variable reflecting unexpected shock in global crude oil markets^⑤. The sample period encompasses annual time series data extending from 1965 to 2020. Descriptive statistics for each of these variables are included in the Table 1. The mean and standard deviation statistics indicate volatility in crude oil price is higher than volatility in crude oil production and volatility in the US dollar price during the sample period. Positive skewness, in most of the variables and high values of excess kurtosis coefficients, reveals the distribution of variables characterized by positive skewness and higher peakness relative to a normal distribution, i.e., it supports the case of non-normality assumption. A positive skewness value reveals a higher probability for price to jump above its mean values during the sample period. The Jarque-Bera (JB) test statistic results reject the normality assumption for all variables. The unit root test of ADF shows evidence

④ The BP statistical review can be accessed at <http://www.bp.com/statisticalreview>.

⑤ Oil production: Includes crude oil, shale oil, oil sands. Oil consumption : includes inland demand plus international aviation and marine bunkers and refinery fuel. Oil refining capacity: Atmospheric distillation capacity at year end on a calendar-day basis.

of random walk behavior for all variables at levels, but stationary at the first difference.

To verify the existence of a long-term association between oil price and the explanatory variables we used Pesaran and Shin (2001) bound testing to test cointegration between the variables^{® [16]}. The lower and upper bounds for the F-test statistic at the 5% and 1% significance levels are [2.32, 3.50], [2.96, 4.26]. As the value of F-statistics = 8.97, exceeds the upper bound value at the 5% and 1% significance level, the bound testing results indicate evidence of long term association between crude oil price and the five fundamental explanatory variables: OPEC and Non-OPEC production; US dollar exchange rate; and World refining capacity expansion, as well as the impact of excess demand due to unexpected shocks like hurricanes.

To estimate the long-term association between crude oil price and the explanatory variables we used three estimation approaches, flexible least squares (FLS), maximum likelihood estimator (MLE), and ordinary least squares (OLS). A distinctive feature of these three approaches is that the FLS and the MLE methods are not necessarily linear in parameters, while the OLS model depends heavily on the assumptions of normality of the residuals and linearity of parameters. Since the basic statistic results in Table 1, support evidence of departure of all variables from the normality assumption, we relied more in our analysis on the FLS and the MLE findings. Since all variables are log-transformed, then each estimated coefficient

is interpretable as elasticity (i.e percentage change of a dependent variable due to 1% change in an independent variable). As indicated in the Table 2, the coefficient values, and the signs of the variables are US\$ exchange rate (x1), OPEC production (x2), non-OPEC production (x3), and refining capacities (x4) in the three estimation approaches are consistent. However, the coefficient signs of supply shock (E) are negative as expected, in the FLS and MLE estimation, but positive in the OLS estimation results, despite its good fitness indicators indicated by the AIC, F test, and the R-square values.

Flexible Least Squares (FLS) estimation results reported in the table below (all variables are log-transformed), indicate that 1% depreciation rate of the US dollar, increase crude oil price (per barrel) by 52 cents; and 1% decrease in OPEC production, increase crude oil price by 10 cents; 1% decrease in non-OPEC production, increase oil price by 1.46 US\$, and 1% increase in refining capacity raise oil price by US\$ 1.80; and finally, unexpected negative supply shock raises crude oil prices by US\$ 1.33. However, according to the MLE method the impact of the US\$ depreciation rate is 71 US cents, and 1% cut in OPEC production increase oil price by 82 US cents, and a non-OPEC production cut raise price by US\$ 4.78, while refining expansion capacities raise oil price by US\$ 4.88. The MLE estimation also indicates the effect of unexpected excess demand shock raising crude oil price, on average, by US\$ 2.36.

Table 1. Basic statistics

	P	X1	X2	X3	X4
Mean	3.7205	11.12	10.209	10.590	11.241
Std. dev	0.66244	0.26	0.25958	0.26705	0.22140
Skewness	0.83	0.11	-1.06	0.86	-0.47
Excess kurtosis	3.12	-0.99	0.74	2.51	0.13
JB test	23.32	2.48	10.56	17.48	1.94
p-value	(0.000)	(0.29)	(0.00)	(0.00)	(0.37)
<u>Unit root test:</u>					
Level	-2.21	-0.41	-2.03	-1.84	-3.52
1 st diff	-6.89	-4.59	-8.04	-15.61	-17.53

Note: X1=US\$ price per gold oz; X2=OPEC production; X3= Non- OPEC production; X4= refining capacities;

© Using the augmented Dicky and Fuller test it has been verified that all variables are integrated of order 1, or I(1) [17]. Table CI (iii) on page 300 of Pesaran et al.2021) is the relevant table to use in our study, as we have not constrained the intercept of our model, and there is no linear trend term included in the ECM.

Table 2. Parameter estimates.

explanatory variables*	FLS		MLE		OLS	
	Mean coefficients	Coefficient of variation	Coefficients	t-ratio	Coefficients	t-ratio
X1 min/max	-0.52 (-0.50/-0.53)	-0.02	-0.71*	-6.50	-0.70*	-5.66
X2 min/max	-0.10 (-0.08/-0.12)	-0.01	-0.82*	-3.27	-0.83*	-3.10
X3 min/max	-1.46 (-1.45/-1.48)	-0.01	-4.78*	-6.59	-4.77*	-6.16
X4 min/max	1.80 (1.80/1.85)	0.004	4.88*	6.02	4.97*	5.50
E min/max	-1.33 (-1.33/-1.33)	-0.0005	-2.36	-1.1	2.27	0.95
Constant	-3.42	-0.0002	3.69	0.82	2.69	0.48
SS residual measurement error = 0.56E-4 SS residual dynamic errors = 0.95E-2 The incompatibility cost = 0.96E-2			Log-Likelihood function = - 10.18		AIC (FPE) = 0.10 F test = 39.56 (p-value) = (0.00) R-square = 0.80	

*Since double log function form is specified, the regression coefficients represent elasticities.

X1=US\$ price per gold oz; X2=OPEC production; X3= Non- OPEC production

X4= refining capacities; E= A sudden excess demand as a measure of adverse supply shocks

5. Conclusions

To verify existence of a long-term association between explanatory variables of crude oil prices including OPEC and Non-OPEC production; US dollar exchange rate; and World refining capacity expansion, as well as the impact of global excess demand shocks, unit root test, and ARDL cointegration analysis employed. The Pesaran and Shin (2001) bound testing results to indicate evidence of a long-term association between crude oil price and the five fundamental explanatory variables^[18]. To estimate the sensitivity of oil price to these variables we used three estimation approaches, flexible least squares (FLS), maximum likelihood estimator (MLE), and ordinary least squares (OLS). A distinctive feature of these three methods is that the FLS and the MLE methods are not necessarily linear in parameters, and distribution-free, while the OLS model depends heavily on the assumptions of normality of the residuals and linearity of parameters.

Estimation results of flexible Least Squares (FLS) method show that 1% depreciation of the US dollar, increase crude oil price (per barrel) by 52 cents; 1% decrease in OPEC production, raise crude oil price by 10 cents; while a decrease in non-OPEC production, increase oil price by 1.46 US\$, and 1% increase in refining capacity raise oil price by US\$ 1.80; and finally, unexpected excess demand shock raises crude oil prices by US\$ 1.33. However, according to the MLE method, which is a more robust estimator, than the other two estimators, the impact

of the US\$ depreciation rate is 71 US cents, and 1% cut in OPEC production increase oil price by 82 US cents, while cut in non-OPEC production, raise the price by US\$ 4.78, and refining expansion capacities raise oil price by US\$ 4.88. The MLE estimation also indicates the effect of unexpected supply shock on average raised crude oil price by US\$ 2.36. Based on the MLE estimation results, it can be deduced that in case a full embargo is imposed on Russian crude oil export, and when no change in OPEC production level in an attempt to compensate Russian oil loss in the international markets, global crude oil price expected to rise by 88 US\$ above its level before Russian–Ukraine war impact, which was about US\$ 75 per barrel[Ⓣ]. However, in the case when OPEC members raise their output level by 10 million barrels per day to compensate for Russian oil loss, global crude oil price expected to increase by 27 US\$ above the initial price level before the Russian–Ukraine crisis.

Conflict of Interest

There is no conflict of interest.

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