

An Overview of Four Factors Affecting Crude Oil Prices: Prices of Li_2CO_3 , EV Sales and Unemployment Rate of the U.S., and The Russian Invasion of Ukraine

Shan Jiang¹, Zehui Han^{2†}, Jingxuan Wang^{3*†}

¹*Department of Economics, University of Essex, Colchester, United Kingdom*

²*Hangzhou. New Channel, Hangzhou, China*

³*Hefei No.1 High School, Hefei, China*

**Corresponding Author. Email: 3372923668@qq.com*

†These authors contributed equally to this work and should be considered as co-second author.

Abstract. As one of the essential commodities in the industrialized world, crude oil casts significant influences on the economic status of the whole world. The highly complicated and volatile crude oil market constantly calls for research that explains price changes and movements. By developing a multiple linear regression and conducting a t-test on the mean comparison, this study demonstrates correlations between the price of lithium carbonate, EV sales in the U.S., the Unemployment rate of the U.S., and the Brent crude oil future price. In addition, the impact that the 2022 Russian invasion of Ukraine imposes on the crude market is analyzed in this study.

Keywords: Crude oil price, Crude oil valuation, Lithium carbonate, Electronic vehicle sales, Unemployment rate

1. Introduction

Crude oil has been playing an elemental role in the industrialized world for past decades, researchers from financial institutions, governments, and the academic world never feel comfortable and satisfied with contemporary searches and studies on pricing and valuating the crude oil price, changes in the price, price movements, as well as searching for new potential influential factors that affect the crude oil price implicitly or directly. Contemporary research has made considerable progressions in introducing oil price-affecting factors focusing on the demand-supply balance of crude oil. However, the role that new-emerged crude oil alternatives like lithium batteries and ongoing geopolitical conflicts like the Russian invasion of Ukraine play in affecting crude oil prices call for constantly updating research to discuss and explain.

This study introduces four factors that potentially affect the crude oil price as well as changes in the price: the price of lithium carbonate, electronic vehicle sales in the United States of America, the unemployment rate of the United States of America, and the Russian invasion of Ukraine in 2022. By developing a three-variable multiple linear regression model, this study demonstrates and

discusses the implications of correlations between the independent variables (the log price of lithium carbonate, the log number of electronic vehicle sales in the United States of America, the log rate of unemployment in the United States of America) and log price of Brent crude oil future contracts that is the dependent variable being explained. To test the significance of disturbance to the crude oil market attributed to the Russian invasion of Ukraine in February 2022, this study compares average crude oil prices after and prior to the Russian attack and discusses the role that it plays in disturbing the crude oil market.

This study is organized as follows: Section II briefly reviews related research, and the methodology of this study will be introduced in Section III. Sections IV, V, VI, VII, and VIII demonstrate and interpret the data and research results of this study. Finally, implications and limitations are discussed in section IX.

2. Literature review

Contemporary studies have made solid progressions in discussing the characteristics of the crude oil market. While high levels of volatility and complexity of the crude oil market have been widely agreed upon in research, changes, and movements in crude oil prices cast significant influences on the global economy. Rafiq, et.al [1] suggested that both increases and decreases in the crude oil price played critical roles in delaying business investments as a result of rising uncertainty of the global macroeconomic status and increased storage and reallocation cost of crude oil. Gormus and Atinc [2] analyze the macroeconomic impact of oil price volatility on the U.S. macroeconomy through a vector autoregression (VAR) model and a generalized impulse response function (GIR), which show that oil price volatility significantly affects economic variables such as GDP, unemployment, and wages, and reveal the transmission paths of oil price volatility on both short- and long-term financial performance. Sköld [3]. On the other hand, takes small open economies such as Sweden, Norway, Denmark and Finland as the subjects of his study, analyzes the cointegration relationship of these variables through autoregressive distributed lag model (ARDL) and error correction model (ECM), investigates the relationship between the unemployment rate and the oil price, the uncertainty of the oil price and the interest rate, and confirms through the Granger causality test that the increase in the oil price has a significant effect on the unemployment rate, especially in oil-importing countries.

A considerable number of studies and frameworks have been conducted to explain changes and movements in crude oil prices, and factors that affect crude oil prices have been dug out and explained constantly. For instance, the role that wars, for instance, played has been widely believed to be an elemental influential factor in crude oil price changes. Zhang, et.al [4] proved that the Persian Gulf War and the Iraqi invasion of Kuwait significantly impacted the crude oil market in the long term.

3. Research methodology

This study adopts two main econometric methods including multiple linear regression analysis, comparison of means, and t-tests to explore the factors affecting the price of Brent crude oil futures. The methodology of this study integrates the characteristics of time series data and ensures the soundness of the results through multiple regression and statistical tests. These research methods ensure a multi-perspective analysis of Brent crude oil price volatility, providing an in-depth understanding of key factors in the crude oil market.

First, a multiple linear regression model is applied to analyze the effects of multiple independent variables on crude oil prices; the independent variables in the model include lithium carbonate

prices, electric vehicle sales in the U.S., and the U.S. unemployment rate. By log-transforming these variables, the study better explains the linear relationship between the variables. Tables 1, 2, and 3 illustrate the statistical information of the regression model. Data on lithium carbonate prices, electronic vehicle sales, the U.S. unemployment rates, and Brent crude oil prices are collected on a monthly basis, the time scope of the data is set from 01, October 2014 to 01, May 2024.

Table 1: Model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.691a	.477	.464	.22066

a. Predictors: (Constant), LnUE, LnEV, LnLi\$

Table 2: ANOVA table

ANOVAa					
Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	5.157	3	1.719	35.307	<.001b
Residual	5.648	116	.049		
Total	10.805	119			

a. Dependent Variable: LnOil\$

b. Predictors: (Constant), LnUE, LnEV, LnLi\$

Table 3: Table of coefficients

Coefficientsa					
Model	Unstandardized Coefficients		Standardized Coefficients		Sig.
	B	Std. Error	Beta	t	
1 (Constant)	.770	.334		2.304	.023
LnLi\$	.130	.032	.327	4.054	<.001
LnEV	.140	.028	.374	5.050	<.001
LnUE	-.226	.088	-.193	-2.559	.012

a. Dependent Variable: LnOil\$

Second, the study used mean comparisons and t-tests to assess the impact of the Russo-Ukrainian war on crude oil prices. These statistical tests helped to identify significant differences in oil price changes before and after the war, further validating the impact of the event on the market.

4. Overview of crude oil price

Data of the Brent crude oil future price (in U.S. Dollars) used in this study contains 120 monthly prices from 01, Oct,2014 to 01, Aug 2024. Table 4 illustrates statistics information of Dollar price (oil\$) and log Dollar prices (LnOil\$). On the one hand, the highest price was found between 01, Feb

2022 and 01, Mar 2022 which was the time Russia invaded Ukraine that implies the existence of a war-related disturbance in the crude oil market. On the other hand, a standard deviation of 18.98 also indicates high volatility of the crude oil market that constantly calls for researches that explain the price movements. Figure 1 illustrates changes in Brent crude oil prices in the given period where the price is marked as oil\$.

Table 4: Descriptive statistics of Brent crude oil prices

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
oil\$	120	22.74	122.84	66.8103	18.97504
LnOil\$	120	3.12	4.81	4.1593	.30133
Valid N (listwise)	120				

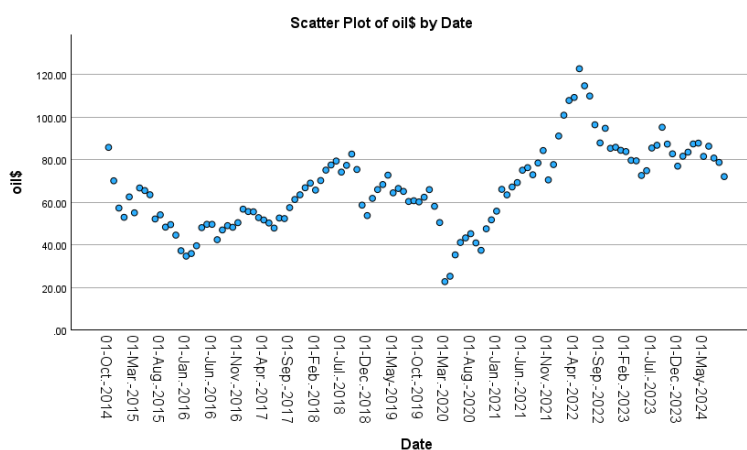


Figure 1: Scatter plot of Brent crude oil prices by date

Note, From Historical Brent Crude Oil Prices, Investing, (2024),

(<https://cn.investing.com/commodities/brent-oil>)

5. Influential factor analysis--lithium carbonate price

Lithium carbonate is one of the main raw materials used to produce lithium batteries that are widely used in EVs, hybrid vehicles, and other type of electronic devices. In 2011, batteries accounted for 27 per cent of the global lithium element [5]. It has become an accelerating tendency that the demand for lithium batteries is increasing constantly because electricity-powered vehicles and devices were introduced into a variety of industries and purposes such as transportation and manufacturing. The projected trend is clear that demand for lithium batteries will continue to increase with the growing production of electric vehicles which may replace internal combustion engine cars and trucks [6]. In addition, the introduction of some highly effective lithium batteries such as the lithium-air battery kept challenging the status of fossil energy including crude oil [7]. While developments in demand and technologies in lithium batteries are gaining a stronger and stronger momentum, it is reasonable to take into account to consider lithium as an alternative energy resource to traditional fossil energy like crude oil.

Statistics information of lithium carbonate prices collected is illustrated in Table 5. Data on the price of lithium carbonate includes 120 monthly prices in the Chinese market from 01-Otc-2014 to 01-May-2024. Table 2 illustrates the overview and basic statistics of the price of lithium carbonate in the U.S. Dollar during the given period. (Where Li\$ stands for the Dollar price that has been translated with a 7.00 CNY/USD exchange rate., LnLi\$ stands for the log price of lithium carbonate priced in U.S. Dollars.)

Table 5: Statistics of lithium carbonate

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Li\$	120	4857.14	80357.14	19944.8810	18451.24984
LnLi\$	120	8.49	11.29	9.5853	.76071
Valid N (listwise)	120				

Note, From Historical Lithium Carbonate Price, Investing [8]

(<https://cn.investing.com/commodities/lithium-carbonate-99-min-china-futures>)

Table of coefficients (Table 6) suggests there is a 0.13 slope of coefficient between log prices of lithium carbonate and log prices of crude oil, and the 4.054 t-value proves the significance at a 95% confidence level. The positive correlation between prices, as well as the price elasticity of lithium carbonate and crude oil explains and supports the aforementioned tendency that lithium gradually became one of alternative energy sources during the given period of time.

Table 6: Table of coefficients

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients		Sig.
	B	Std. Error	Beta	t	
(Constant)	.770	.334		2.304	.023
1 LnLi\$	.130	.032	.327	4.054	<.001
LnEV	.140	.028	.374	5.050	<.001
LnUE	-.226	.088	-.193	-2.559	.012

a. Dependent Variable: LnOil\$

The slope coefficient is not only significant from the perspective of statistics but also makes sense from a practical perspective. That is, on the one hand, an increased price of lithium carbonate leads to a higher cost of lithium batteries that not only forces up the price of downstream products including EVs, but also diminishes downstream industries' willingness and ability to replace crude oil with electricity as the main energy sources. As a result, increased projected demand and real consumption of crude oil led to high prices. On the other hand, lower lithium carbonate prices allow downstream mass productions of lithium batteries at low cost from raw materials and sequentially brighten the outlook of fossil energy replacement that presses down crude oil prices.

6. Influential factor analysis--EV sales

As a strong competitor to traditional gasoline vehicles, EVs (electric vehicles) are a significant factor influencing the crude oil market. And the EV industry is also one of the main consumers of lithium carbonate which is used as the raw material of batteries. To slow down the climate change by cutting the emission of green gases, the demand for the EV has grown rapidly in a decade. The global electric vehicle market continues to expand, and governments at all levels are continuously seeking to accelerate growth. In 2015, about 115,000 electric vehicles were sold in the United States, accounting for about a fifth of global sales of electric vehicles [9]. In addition, according to Slowik [10], global cumulative electric vehicle sales had surpassed 2 million units, with growth continuing in the major markets of China, Europe, and the United States. And US is famous for its mature technology for EVs and the famous international EV company Tesla, the data from the US is representative in some ways.

The data on the EV sales from DOE includes 120 monthly selling amounts from 01-Oct-2014 to 01-May-2024 of EV in the US.

Table 7: Independent sample test

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
EVSales	120	8000.00	118000.00	43968.3333	31455.50942
LnEV	120	8.99	11.68	10.3989	.80667
Valid N (listwise)	120				

Note, from Historical EVs sales, EV Volumes, [11], EVs sales, IEA50, [12]

(<https://ev-volumes.com/product/car-to-market/>, <https://www.iea.org/>)

Information on the regression shown in Table 7 indicates that while holding other variables constant, the log sales number of electric vehicles increasing by one unit corresponds to a 0.140 unit increase in log oil prices. An explanation from the practical perspective is that, on the one hand, increasing the number of EVs will dilute part of the market share of gasoline vehicles which is one of the main consuming sectors of crude oil, and shrink the profit of the crude oil industry. As a result, investments in the production of the oil industry such as crude oil exploration and petroleum refining would also decrease which may impede further improvements in the productivity of crude oil that would indirectly cause crude oil prices to rise. On the other hand, robust EV sales boost the demand for oil oil-based materials used to produce accessories and parts of electronic vehicles and lead to higher crude oil prices. Moreover, a stronger economic performance reflected by increased EV sales also plays a role as a main contributor to increases in crude oil prices.

7. Influential factor analysis--U.S. unemployment rate

The U.S. unemployment rate is a key factor affecting the price of Brent crude oil. Table 8 gives statistics information of U.S. Unemployment rate.

Table 8: Table of coefficients

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
UE	120	.03	.15	.0474	.01744
LnUE	120	-3.51	-1.90	-3.0637	.25638
Valid N (listwise)	120				

Note, from Historical Data of U.S. Unemployment Rate, Investing, (2024)

(<https://www.investing.com/economic-calendar/unemployment-rate-300>)

The regression results in Table 9 indicates that there is a significant negative relationship between the unemployment rate and oil prices. Specifically, the regression coefficient for the U.S. unemployment rate is -0.226 with a statistically significant p-value of 0.012. This negative coefficient suggests that Brent crude oil prices tend to decline as the unemployment rate rises. This can be explained by the fact that a rise in the unemployment rate usually reflects a slowdown in economic activity. As the unemployment rate rises, industrial production and consumer demand for goods and services usually fall, which leads to a decrease in the demand for oil and a consequent decrease in the price of oil. On the other hand, when the unemployment rate falls, it signals a stronger economy and an increase in industrial production and consumer demand, which in turn pushes the price of oil up due to increased consumption.

Table 9: Table of coefficients

Coefficients ^a					
Model	Unstandardized Coefficients		Standardized Coefficients		Sig.
	B	Std. Error	Beta	t	
(Constant)	.770	.334		2.304	.023
1 LnLi\$	.130	.032	.327	4.054	<.001
LnEV	.140	.028	.374	5.050	<.001
LnUE	-.226	.088	-.193	-2.559	.012

a. Dependent Variable: LnOil\$

The negative correlation between these two variables highlights the importance of macroeconomic indicators such as employment levels in determining global oil demand and pricing. As unemployment rises and the economy slows, oil demand weakens, leading to lower prices. Conversely, low unemployment and a strong economy drive up demand and raise oil prices.

8. Influential factor analysis--Russian invasion of ukraine

To gain a clearer understanding of the impact of the 2022 Russian invasion of Ukraine, this study divides the oil price data into two distinct groups: the pre-war period and the post-war period, where group war 1 in showed in Table 10 stands for the price before the war, and war 2 shows average prices after the invasion. This division allowed us to compare and contrast the prices, thus showing

the full extent of the war's impact on the market. Table D illustrates the average prices of Brent crude oil prices before and after the 2022 Russian invasion of Ukraine

Table 10: Group statistics of average prices before and after the Russian invasion

Group Statistics					
	war	N	Mean	Std. Deviation	Std. Error Mean
oil\$	1.00	88	58.7499	13.81142	1.47230
	2.00	32	88.9766	12.45655	2.20203
LnOil\$	1.00	88	4.0428	.25785	.02749
	2.00	32	4.4796	.13229	.02339

Further, this study conducts a t-test to measure the difference in mean prices between the two groups. The t-test results are illustrated in Table 11. The t-statistics suggest a significant difference emerged, with the pre-war mean price at \$58.7499 and the post-war mean price jumping to \$88.9766. This substantial shift underlines the profound impact of the conflict on oil prices.

Table 11: Independent sample test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
oil\$	Equal variances assumed	1.191	.277	-10.872	118	<.001	<.001	-30.22668	2.78035	-35.73253	-24.72083
	Equal variances not assumed			-11.411	60.597	<.001	<.001	-30.22668	2.64889	-35.52417	-24.92919
Ln Oil\$	Equal variances assumed	11.470	<.001	-9.139	118	<.001	<.001	-.43685	.04780	-.53151	-.34219
	Equal variances not assumed			-12.105	104.647	<.001	<.001	-.43685	.03609	-.50841	-.36529

The analysis of the Russian invasion of Ukraine yields two key insights. First, the war has affected crude oil by introducing a new level of volatility and uncertainty. Second, from an average perspective, the conflict pushed the average price of crude oil to new heights. This increase can be attributed to various factors, including disrupted supply chains, heightened geopolitical tensions, and market speculation stimulated by fear and uncertainty. In addition, The significant difference in average prices between the two groups is evidence of the war's far-reaching impact on the oil

market. It's not just about the numbers, but the human stories behind them. The war has had a ripple effect, affecting everyone from politicians to investors to ordinary consumers. The market's reaction to the risk of war is a clear indication of the deep-seated fears and concerns about potential supply disruptions and price volatility. It's critical to recognize the lasting impact of the Russo-Ukrainian conflict on crude oil prices. By analyzing the data and understanding the underlying tendency, it can be helpful to investors to better prepare for potential future volatility in the crude oil market. Policymakers, investors, and consumers must remain vigilant and closely monitor international developments to anticipate and respond to changes in the oil market.

The Russian-Ukrainian war has left an indelible mark on the crude oil market. By splitting the data, running a t-test, and analyzing the results, this study gained a deeper understanding of the war's profound impact on oil prices. It's a reminder that geopolitical events can have far-reaching consequences, and all stakeholders need to remain aware and adaptable in the face of uncertainty

9. Conclusion

This study explains the movements of the Brent crude oil future contract between 2014 and 2024 with the three-factor multiple linear regression and mean comparison of the average prices before and after the Russian invasion of Ukraine in February 2022. Both of the two approaches provide meaningful explanations for crude oil price changes. Put in detail, the three independent variables in the aforementioned regression model explain the crude oil price change from a different and creative angle: 1, to price, value, and predict the spot price and the future contrast's price of crude oil, data of crude oil substitutes such as lithium batteries prices and Electric Vehicles sales can be taken into account. In the regression model, the positive slope coefficients observed in the log price of lithium carbonate explain the change in crude oil prices by assuming higher prices and higher crude oil substitutes stimulate crude oil demand and consumption and lead to an increased price of crude oil. 2, economic performances of the main crude oil consumption countries such as the United States and China impose significant influences on the global crude oil market as well as the crude oil price. The negative correlation between the log rate of the American unemployment rate and the log crude oil price revealed in the regression result table indicates that a lower American unemployment rate contributes to increased crude oil prices to some extent. 3, the 2022 Russian invasion of Ukraine sparked a sharp increase in the crude oil price. Even though the Brent crude oil futures price dropped several months after February 2022, the mean comparison suggests that the Russian attack still forces up the average crude oil price and leads to the crude oil markets becoming more volatile. Finally, this study was conducted with a certain scope and has some limitations. First, the linear regression model applied in this study may over-simplify the complexity of the real-world crude oil market and its price movements. Second, data collected from certain regional markets such as Lithium carbonate spot prices in the Chinese market and electric vehicle sales in the United States of America reflect limited portions of the whole picture of the influential factor. Future studies can put more effort into developing more comprehensive predicting models and increasing data scales.

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Zehui Han, Jingxuan Wang contributed equally to this work and should be considered as co-second author.

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