

BSTS Model for Crude Oil Price Forecasting: A 12-Month Analysis

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Abstract. Crude oil plays a very important role in the development of the world getting faster and faster. Since it is not renewable, people significantly care about this precious and limited resource that occurs everywhere in their daily lives. In recent years, the fluctuation of crude oil prices varied frequently. Therefore, what the oil price will change in the future becomes a very big problem that people care about. Among plenty of models, this paper will use the Bayesian structural time series (BSTS) model to forecast the future trend of crude oil prices within the next 12 months and the possible factors that could cause this trend. Based on the analysis by employing the BSTS model, the forecasting result of the future oil price shows that the crude oil price might increase at a relatively slow rate. Based on this trend, all the factors that could cause the oil price to rise are possible to happen, meaning that considering these factors when making decisions such as investment is important.

Keywords: Crude oil price, BSTS model, Oil market trends.

1. Introduction

Crude oil, as an unrenewable resource, is used in various areas. It is not only the main energy supply resource, but also the foundation of the material industry [1]. It is a raw natural resource extracted from the earth and refined into products such as gasoline, jet fuel, and other petroleum products [2]. It is composed of hydrocarbon deposits and other organic materials that were formed from the remains of animals and plants that lived millions of years ago. In this case, the fluctuation of the crude oil price can create a huge effect on the world economy. The supply and demand of crude oil will be affected easily.

West Texas Intermediate (WTI) crude oil is one of the three major oils for trading all around the world. This crude oil belongs to the United States. During 2013, the oil price maintained at a relatively high level. However, in the middle of 2014, the oil price decreased due to the increasing supply with decreasing demand for it in developing countries [3]. From 2015 to 2016, nothing was done to stabilize the oil price until some oil exporter countries decreased their supply. In 2020, COVID-19 appeared, generating a very severe negative effect on the oil price. It even reached the lowest price in the past 13 years. As the economy recovered gradually in 2022, the military conflicts between Russia and Ukraine raised the oil price to the highest point. During the past 13 years, the fluctuation of crude oil prices made future prices unpredictable in simple methods. As a result, this paper mainly concentrates on forecasting the crude oil price in the next 12 months and analyzes the possible factors that might cause this trend by using the Bayesian structural time series (BSTS) model.

2. Method

BSTS is a statistical technique that could be used to do time series forecasting. The data input should be time series data. Since it could deal with scale larger-scale exogenous data, it might be a superior tool to use than other models like Autoregressive Integrated Moving Average (ARIMA), Exponential Smoothing State Space (ETS), or other techniques to analyze time series models. Moreover, this BSTS model can also be converted into a time series model with a more complicated structure, enhancing the precision of the results [1].

To build the time series model, data selection and cleaning is crucial. A wider range of data captures the trend of the fluctuation better and predicts the future trend more precisely. In this case, the selected dataset range is from October 2010 to October 2023, which is thirteen years. However, the data records the oil price daily instead of monthly or yearly, which makes the plot less clear to observe the specific period of fluctuation of the crude oil price. And for yearly oil price prices, it decreases the precision of the model. Therefore, monthly data could be the best choice. In the dataset, there are two variables: date in months and average monthly oil price in US dollars. The analysis will focus on the forecasting of the oil price trend in the next year. Compared to forecasting more years, paying attention to the next year gets a more accurate consequence of prediction

3. Result

Before running the data in the BSTS model, an important check is to figure out whether the time series is stationary. First, set the null hypothesis to be that the time series is non-stationary and the alternative hypothesis to be stationary. The ADF test indicates that the p-value is 0.03444 which is less than 0.05, meaning that the null hypothesis could be rejected, so the time series is stationary, which demonstrates that the mean, variance, and autocorrelation structure will vary over time.

Fig. 1 reveals the visualization of the monthly WTI crude oil price changes from October 2010 to October 2023. The vertical axis represents the crude oil price in US dollars. The horizontal axis represents the date in years. From the figure, it is obvious that the fluctuation of the oil price is not stable. From October 2010 to June 2014, the price kept fluctuating but the trend gradually increased, maintaining a high price. Then a serious drop started in February 2016. After that, the price recovered a little bit, but another sudden decrease occurred in December 2019. In about April 2020, it reached its lowest price level and quickly recovered until reached its highest point in June 2022. Then it went down for a year before the next increase.

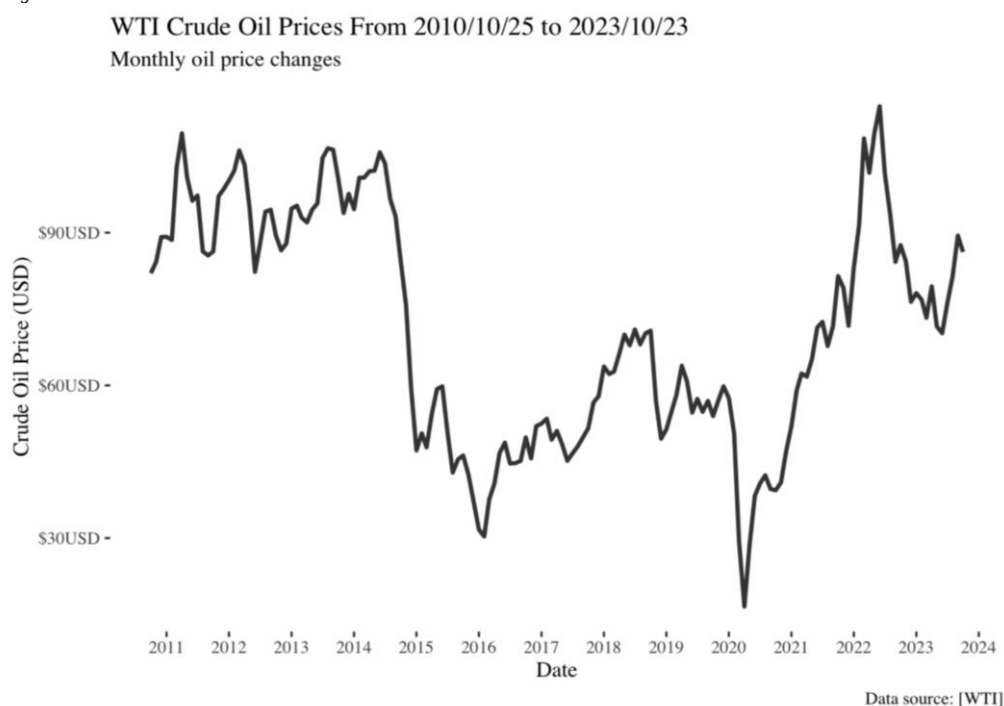


Fig. 1 Visualization of WTI crude oil price (Photo/Picture credit: Original).

The final forecasting result is shown below in Fig. 2. The red line shown in the plot is the observed data from the previous thirteen years. In the blue-shaded area, which represents the 95 percent confidence interval, the blue line is the predicted data trend for the next 12 months. In 2024, the WTI crude oil price tends to be slightly increasing. However, the accuracy check indicates that the mean absolute percentage error is about 41%, meaning that the result is a relatively low accuracy.

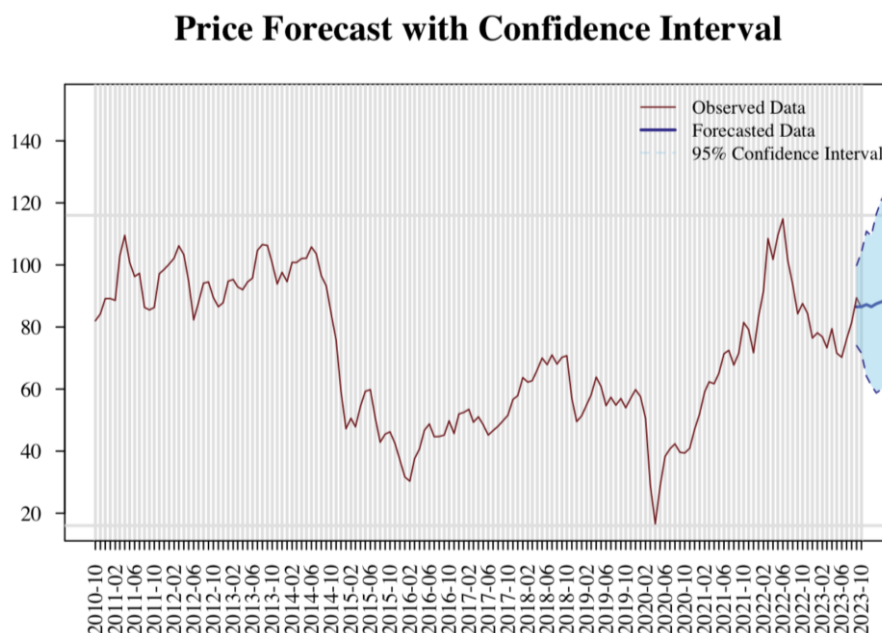


Fig. 2 Forecasting result of oil price next year (Photo/Picture credit: Original).

4. Analysis and Discussion

According to the visualization of the crude oil price cross 13 years, the fluctuations of the crude oil price happened resulting from factors including adjustments of OPEC (Organization of the Petroleum Exporting Countries), COVID-19, fiscal and monetary policies of the U.S., the effect of substitutes, wars, and other economic actions. Although sudden shocks in the economy and the supply and demand of oil could have the most severe impact on changing the oil price greatly, all these factors could cause drastic changes in oil prices in some cases, so this part will mainly focus on elaborating how they influence the crude oil price from economic aspects.

The first factor that will be analyzed is the policy adjustments of OPEC. It significantly affects the crude oil price by controlling the supply of their oil. This is the most direct way to influence the oil price. In a supply and demand curve at short-term equilibrium, if the quantity supply of crude oil decreases, it means that the availability of crude oil decreases. Thus, the supply curve will shift to the left, leading to an increase in price. In about Jan 2015, since OPEC refused to stabilize the crude oil price by decreasing the supply of oil, oil prices kept decreasing [3]. If OPEC kept a high oil supply, the supply curve would shift to the right, causing the run short-run equilibrium to move downward. So, the oil price decreased. Besides, the shift in the demand curve possesses the same ability to set the price. Under these circumstances, from June 2014 to Feb 2016, the oil price decreased badly.

From 2020 to March 2022, due to COVID-19, people reduced the possibility of going out, decreasing the utilization of vehicles and all transportation tools. According to research, the number of reported deaths could be another significant factor that led to low oil prices [4]. As a result, the oil demand dropped dramatically and the whole economy fell into a severe recession. And the occurrence of the tremendous economic recession negatively affected the oil price. The oil price rapidly decreased to a very low level. Since the population rapidly decreased, the number of consumers of oil products decreased as well. This decreased the oil demand. In April 2020, the WTI oil price reached 36.98 US dollars per barrel [4].

To adjust oil prices, as part of the monetary policy, the exchange rate is what each country will change to adjust the oil price. The changes in the exchange rate will cause depreciation and appreciation. Before the currency is going to depreciate, the oil price contract tends to be signed [4]. Based on the content of the contract, oil exporters decide to export less oil to stabilize the oil price. So, the quantity of foreign currency decreases, and the willingness to use domestic currency increases. Automatically, the exports will increase again.

From the economic side, in June 2014, the increasing production capacity of the USA and the reduced demand for oil in developing countries decreased the oil price [4]. As explained above, the action of the USA tended to decrease the oil price. The oil demand decreased, meaning that the demand curve shifted to the left and decreased the price level, too.

Wars between countries could also be a factor that affects the oil price. In March 2022, the Russia–Ukraine conflict created high inflation which increased the oil price to some degree. Inflation shows a sustained rise in the overall price level. High inflation means the rise is very large and this signals an overheated economy [5]. In rapid economic growth, the demand tends to increase apparently in a short time, followed by a faster increase of supply and reaching the short-run equilibrium. Since Russia is one of the main producers of crude oil, this conflict benefited other oil-exporting countries. WTI crude oil as a substitute for Russian crude oil became an appropriate source to import for other countries that needed crude oil. As the demand for WTI crude oil increased, the demand curve shifted to the right and increased the oil price. Several months after the beginning of the conflict, the inflation was adjusted, and the oil price started to fall until June 2023. Recently, the Israeli–Palestinian conflict has become heavier than before. However, since these two countries are not major oil exporters, the influence on the oil price will not be as obvious as the previous conflict mentioned above.

These factors will affect crude oil prices in the future. As the forecasting result shown in the previous section, the oil price tends to be slightly increasing. Based on the analysis of each factor, a decrease in the oil supply of OPEC, change in the exchange rate, wars, et al. have the probability to increase the oil price. Consequently, the increase in crude oil prices might be the result of one or more of them.

5. Conclusion

As an important portion of the world economy, crude oil change could influence the economy, political, military, and other related aspects to different degrees. By predicting the future trend of the oil price change, companies and individuals could benefit through the decision-making. According to the analysis, the major factors that could affect the crude oil price are political adjustments by OPEC, epidemics such as COVID-19, the exchange rate, and military conflicts. Each of them impacts the oil price negatively or positively. The forecasting result indicates that the future crude oil price probably will increase, meaning that some of these factors tend to increase the oil price. This provides people with directions to observe and consider before making any related decisions. Since the model for this paper is relatively simple, the result might not be that precise. And because the analysis of factors is limited to a certain amount, there might be new factors occur and affect the oil price in the future.

References

- [1] Jianwei E, Bao Y, Ye J. Crude oil price analysis and forecasting based on variational mode decomposition and independent component analysis. *Physica A: Statistical Mechanics and its Applications*, 2017, 484: 412-427.
- [2] Lu Q, Li Y, Chai J, et al. Crude oil price analysis and forecasting: A perspective of “new triangle”. *Energy Economics*, 2020, 87: 104721.
- [3] Liberto D. What is crude oil, and why is it important to investors? 2022.
- [4] Yang Y T, Yang T Y, Chen S H, et al. Exploring the non-linearity of West Texas Intermediate crude oil price from exchange rate of US dollar and West Texas Intermediate crude oil production. *Energy Strategy Reviews*, 2022, 41: 100854.
- [5] Le T H, Le A T, Le H C. The historic oil price fluctuation during the Covid-19 pandemic: What are the causes? *Research in International Business and Finance*, 2021, 58: 101489.