http://dx.doi.org/10.12785/ugric/2026011

Forcasting Brent Crude Oil Prices using Monte Carlo Simulations and Prophet Models

Shrikant Krupasindhu Panigrahi
Economics and Finance Department
University of Bahrain
Sakhir, Bahrain
0000-0003-1703-4613

Mustafa Jaffer Ali Al-Annan
Management and Marketing Department
University of Bahrain
Sakhir, Bahrain
202102101@stu.uob.edu.bh

Ali Ebrahim Ali Buhmaid
Management and Marketing Department
University of Bahrain
Sakhir, Bahrain
202204554@stu.uob.edu.bh

Abstract: **Crude oil is one of the most critical energy commodities, and thus understanding its price dynamics remains a central issue for researchers. This paper applies innovative methods to predict crude oil prices over the period 2019-2025. Daily crude oil price data obtained from Yahoo Finance are employed to develop and compare two forecasting approaches: Monte-Carlo simulation and Prophet model. The Monte Carlo simulation was chosen because of its nature in dealing with uncertain events by following a stochastic framework that depicts thousands of random events that rely on past crude oil price behaviors, macroeconomic conditions, and other factors through generating multiple price paths. In contrast, the long-term trends, seasonality and non-linearity in the model were handled by utilizing the Prophet model. Empirical results indicate that the Prophet model outperforms the Monte Carlo simulation in terms of predictive accuracy and systematic trend identification. However, Monte Carlo remains more effective for understanding uncertain events. Combining both models provides a comprehensive analytical framework that enhances long-term forecasting reliability and supports informed decision-making for investors and market stakeholders.**

Keywords: *Crude oil, Price Prediction, Monte Carlo Simulation, Prophet, Random Forest, Time Series Forecasting, Machine Learning.*

I. INTRODUCTION

Crude oil, or as it is called “Black Gold”, is one of the most influential commodities that has a great effect on economic factors such as inflation, GDP, and interest rates, and even investment decisions that investors make [6]. As crude oil plays a major role in the energy sector, accurate projections of its future price have become a primary task for investors, policymakers, and even governments to mitigate the potential risks and draw future strategies. Due to the importance of Crude oil in the financial market, its price has high volatility and may face unpredictable shocks that can highly affect its price in either positive or negative way, such as political events, supply and demand imbalance, news, OPEC production policies, natural disasters, and even the shifting trials to electrical-based world to avoid pollution resulting from the oil consumption [9]. These high fluctuations in crude oil prices make the forecasting task more complex, as both short-term and long-term fluctuations affect the market behavior simultaneously.

To handle these complications, several advanced forecasting technical models were combined from machine learning models and some statistical models to consider all historical market movements and real-time market behavior patterns [7]. Numerous studies have included traditional econometric methods like vector autoregressive (VAR) and the generated autoregressive conditional heteroskedasticity model (GARCH) and the autoregressive integrated moving average (ARIMA) models, however, were unable to predict effective the nonlinear effect [3]. Currently, machine learning models are heavily used amongst scholars to predict nonlinear information and apply historical information [4].

Advanced forecasting models such as the Monte Carlo and Prophet models were used to map future crude oil price trends, detect market volatility, and determine the margin of error, also known as the standard deviation. By combining machine learning and econometric rigour, the researchers will be allowed to deal with nonlinear models and other unobserved factors like trading volume. Through this enhanced forecasting framework, the results of analytics, informed decisions, and risk management have become more accurate and dependable.

II. LITERATURE REVIEW

Crude oil price fluctuations play a significant role in shaping global economic and energy decisions, and they have attracted the researchers' attention to study their impact in academic literature. Several studies have proven that Crude oil is considered a commodity whose price fluctuations affect exchange rates, inflation, economic growth, and the financial market. As a result, various forecasting and projection techniques were inspected by researchers to enhance the accuracy and reliability of the process of price forecasting. Past literatures reveal that the conventional models are still the most used; however, the latest literature strongly depends on machine learning models in projections and reveals the market and crude oil price movements.

The impact of crude oil price fluctuations has been discussed in many past studies, as mentioned before, it is a major economic commodity that affects macroeconomic factors. Alquist and Coibion [1] highlight in their commodity prices fluctuations analysis that large movements in crude oil and other commodity prices often synchronize with macroeconomic instability periods. These shocks in commodity prices were explained as a crucial source of exogenous economic volatility, influencing aggregate output, business cycle, and even inflation. In addition, they noted that the stagflation of the 1970s is frequently attributed to intense increases in oil and other commodity prices, which contributed to economic downturns and inflation. Furthermore, the authors point to the earlier findings of Hamilton's paper, which says that most of the recessions in the United States were preceded by oil price expansions, enhancing the linkage between oil prices and the macroeconomic execution. Moreover, the paper asserts that commodity price movements have an impact on supply and demand, making oil a major driver of international economic instability.

Several models are used to forecast future outcomes, such as prices. For instance, Cheng et al. [2] point out that the Autoregressive Integrated Moving Average (ARIMA) model is still a foundational tool used in the projections of crude oil prices because it can reveal short-term dependencies within time series data and linear patterns. In their paper, they use the ARIMA model to draw the patterns of future behavior of each component analyzed from oil prices, that is, the shocks from utmost events, the volatility of the market, and long-term trends, after the usage of CEEMD analysis that isolates the noise and separates the series into meaningful frequency bands. Therefore, the ARIMA model at this level provides an effective measurement of expected movements before applying the SVM model for nonlinear optimization. Other up-to-date studies have asserted the significance of volatility modelling, mainly when the behavior of the oil market is affected by structural breaks.

Odu et al. [7] show that the price of crude oil bears material volatility during the period of major economic shocks, as an example COVID-19 pandemic, which caused significant structural breaks and extraordinary fluctuations in both markets, BRENT and WTI. The results of their study demonstrate that using conventional linear models alone is not a good idea, as these models are unable to fully cover these dynamics, specifically when there is a change in the variance of oil prices due to a global crisis.

A great model used in this research paper is the Monte Carlo simulation, which this model used to simulate crude oil prices before. Divyaa et al. [5] show that the Monte Carlo model is an important simulation method used in monitoring crude oil price forecasting uncertainties through generating several possible price paths based on historical macroeconomic conditions. Related to their application of Monte Carlo simulation, after making the regression analysis model, and connecting the major economic indicators with WTI prices, they run 1000 Monte Carlo iterations to visualize random fluctuations and arbitrary market states. Overall, Monte Carlo simulation allows for categorizing outcomes into best-case, base-case, and worst-case scenarios, providing a substantial perception of risk exposure and delegating more knowledgeable decision-making for investors and policymakers.

Based on Ma [6] research, the FB Prophet model offers productive experience in forecasting crude oil prices through analyzing time-series data into trend, seasonality, and irregular components. Also, it offers the ability to capture nonlinear patterns while remaining robust to missing values and outliers, so it remains suitable for fluctuating commodity markets. Ma, in his research paper, demonstrates that the Prophet model detects trend alterations and different seasonality, which enables the model to identify long-term and short-term fluctuations. In the conclusion of the study, Ma points out that the Prophet model produces well-founded forecasts and projections, outperforming several traditional time-series models in identifying overall price trends.

Firstly, both models are useful in predicting crude oil price paths, so by using them both, a comprehensive overview of the aspects of the price prediction, such as uncertainty and long-term price behavior. Monte Carlo simulation is an ideal model in risk assessment, as it generates dozens of price paths based on historical volatility and macroeconomic randomness. On the other hand, FB Prophet produces stable and interpretable forecasts of crude oil prices through modeling trends and seasonality. While Monte Carlo focuses on generating probabilistic scenarios, FB Prophet highlights structural patterns.

TABLE I KEY FINDINGS FROM PREVIOUS STUDIES

Author(s) & Year	**Title**	**Key Findings**
Alquist and Coibion [1]	The Comovement in Commodity Prices: Sources and Implications	Crude oil price fluctuations have a clear impact over Macroeconomic conditions.
Cheng et al. [2]	A CEEMD-ARIMA-SVM model with structural breaks to forecast the crude oil prices linked with extreme events	It shows how traditional models are used in predicting crude oil prices.
Odu et al. [7]	MODELLING OIL PRICE VOLATILITY WITH STRUCTURAL BREAK: A RE EXAMINATION	Shows that Structural breaks are used in past research and need Linear regression to proceed.
Divyaa et al. [5]	Predicting Macro-Economic Factors of WTI Crude Oil Using Monte Carlo Simulation	How Monte Carlo simulation is a crucial model to forecast prices of crude oil through generating scenarios.
Ma [6]	Research on Crude Oil Price Forecasting Technology Cased on Fbprophet	Prophet model offers enhanced experience in crude price projections through modeling the time-series trends and seasonality.

Based on the reviewed literature, crude oil prices have a considerable impact on macroeconomic factors, impacting the whole economic cycle, inflation, and financial stability. Past research used traditional models in their studies, like ARIMA, which capture short-term linear patterns in an effective way; however, it considers structural breaks as obstacles, as shown in the COVID-19 case. On the other hand, the latest studies Kaymak and Kaymak [8] assert that hybrid approaches and volatility modelling result in better accuracy. Monte Carlo provides enhanced forecasting through generating probabilistic scenarios that show market uncertainty, where a powerful performance in catering trends is presented by the Prophet model. In conclusion, contemporary research favors machine learning and hybrid models for more reliable crude oil price forecasting.

III. METHODOLOGY

Data Source

For analysis and forecasting purposes, this paper relied on time-series secondary data from the reliable Yahoo Finance financial database. Crude oil data used in the forecast were collected based on daily prices from January 2019 to October 2025. The starting year was chosen before the COVID-19

pandemic to accurately illustrate its impact on crude oil prices in past years, as well as on projected future prices.

The reason behind choosing Yahoo Finance as the primary source of financial data was the accuracy, reliability, and the updates they conduct over their data, which, as a result, offers the opportunity to outcome at a highly realistic future price forecasting.

In addition, the extracted data was downloaded, processed, and cleaned by using Python to handle missing values, and validate outliers to avoid any irregular patterns in the future, and also the data was prepared to be able to run forecasting models like Monte-Carlo Simulation, Random Forest Model, and FB Prophet model, as these models require specific specifications that must be exist to run properly.

Prophet Model

One of the models utilized to forecast future crude oil prices in this research was the Prophet model, an innovative tool used in a time-series forecasting framework developed by Meta's data science team. The Prophet model was chosen to be used in this research because of its ability to deal with complex trends like crude oil prices, which are characterized by their seasonality, irregular movements, and sensitivity toward geopolitical events that can't be handled in nature. A very important feature that the Prophet model includes is its ability to deal with outliers, missing values, and even non-linearity issues while forecasting, which is considered a competitive advantage that the Prophet model has. Related to its operations, the model catches both long-term and short-term oscillations through analyzing time series into trend and seasonality components, which enables it to detect the significant shift points in an automatic way, then adjusts the model based on these detections to enhance the forecasting accuracy. FB Prophet model capabilities help in getting outcomes that are interpretable and reliable projections, making it specifically useful in volatile markets such as crude oil.

Monte Carlo Simulation

The second model used in this research is the Monte Carlo simulation model, which is one of the most famous models used, especially in forecasting crude oil prices and in general for analyzing uncertainty in financial securities and commodity markets. Because of the pure relationship between crude oil prices and geopolitical and other events, Monte-Carlo is used to handle these factors, which could capture the randomness and inherent volatility of crude oil prices that are caused by macroeconomic fluctuations, geopolitics, and even market shocks. Monte-Carlo makes its outcomes through generating multiple potential price paths through resampling from probability distributions derived from historical crude oil data. So, rather than giving a single forecast, Monte Carlo generates a wide range of reasonable results from future prices. The model significantly relies on daily returns, past volatility, and random differentials in oil price to represent the way crude oil prices behave over a given period. Each generated line represents a different course of randomness of price behavior, and the overall distribution of all simulations illustrates the likelihood of various price outcomes in different scenarios, i.e., best-case, base-case, and worst-case scenarios. Finally, Monte-Carlo was chosen because of its great ability to offer valuable support for strategic planning and decision-making in highly uncertain energy markets.

IV. Results

The Prophet model and the Monte Carlo Simulation are two methods used to forecast and analyze crude oil prices. The Prophet model focuses on predicting future oil price trends using historical data. Prophet identifies seasonal changes and long-term trends, while Random Forest captures complex patterns and external factors such as global demand, production levels, and political events. Together, they provide accurate and stable forecasts with confidence limits, helping investors and policymakers' plans. However, this model may not react well to unexpected events that do not follow past patterns.

The Monte Carlo Simulation, on the other hand, studies risk and uncertainty by running thousands of random simulations to show many possible future oil prices. It doesn't give one fixed prediction but instead shows best, worst, and average scenarios based on probability. This makes it valuable for understanding market volatility and preparing for sudden price changes. However, its accuracy depends on the quality of input data and assumptions. In summary, the Prophet model is better for forecasting long-term price movements, while the Monte Carlo Simulation is stronger for risk assessment and scenario analysis. Together, they provide a clearer and more complete understanding of the crude oil market.

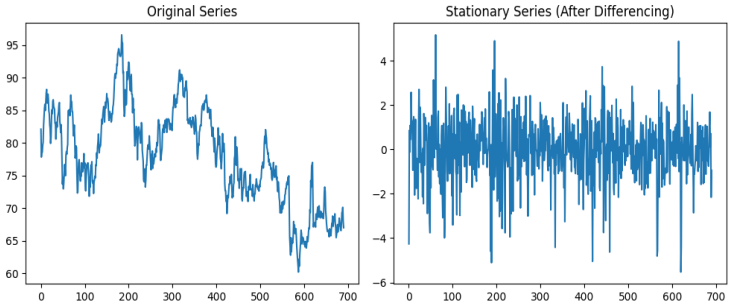

FIGURE I: UNIT ROOT TEST BEFORE AND AFTER FIRST DIFFERENCING

TABLE II UNIT ROOT TESTS

ADF Test Before & After Adding Lags		
	0 Lag	**2 Lag**
Observations	690	687
Test Statistic	-2.396	-15.818
P-Value	0.143	1.027713453438519e-28
Critical Value 1%	-3.440	-3.440
Critical Value 5%	-2.866	-2.866
Critical Value 10%	-2.569	-2.569
Stationarity Status	NOT stationary	stationary

Table II illustrates the unit root test for crude oil forecasting. From the results, it can be seen that at lag 0, the data were not stationary, but after the first divergence with lag 2, the data were found to be stationary and reliable. As shown in graph

(a), the series exhibits clear volatility with trends, suggesting a non-stationary model (high fluctuations in the mean and variance). The p-value reported in Table 1 is 0.143, indicating non-significance. On the other hand, graph (b), which illustrates the unit root model after differencing (by adding 2 lags), still indicates volatility, but this time it is around a stationary mean (almost zero). Therefore, we can conclude that the model is now stationary, as the p-value is less than 0.01 and also 0.05, indicating significance.

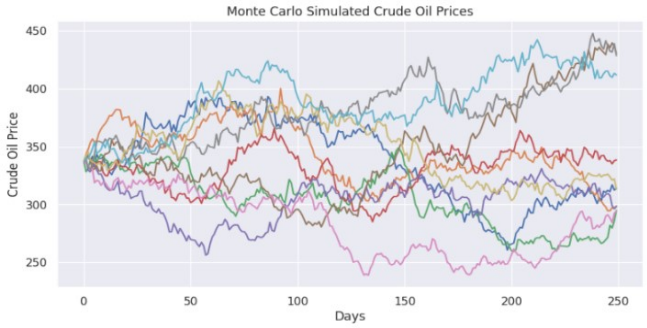

FIGURE II MONTE CARLO PREDICTION

Figure II shows the possible price paths under uncertainty that are randomly generated by a Monte-Carlo model that assesses the risk and exposure, and volatility. Each line in the graph represents a single possible future price path over a specified period(in this model is 250 days). In the extracted graph, Monte-Carlo shows high volatility as the price lines are more widely spread from each other, which shows a level of uncertainty related to the prices of crude oil. As shown, the initial price the model started with is around $300, representing the current crude oil price used in the model. The short-term movements (0-50 days), the model shows relatively clustered prices, indicating low short-term uncertainty. In the medium-term period (50-150 days), the price paths begin to separate in a significant way, representing increasing uncertainty over time. Finally, the long-term movement (150-250 days) shows a much wider spread of paths, which means the uncertainty will be higher and higher. The upper limit of prices the model reached is above $420, while the lower is under $250.

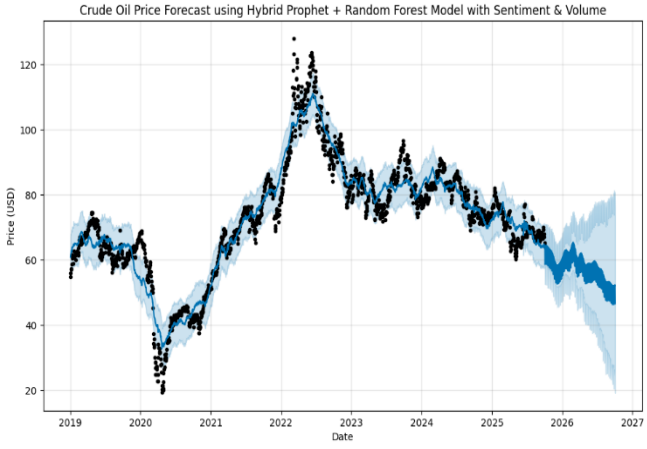

FIGURE III PROPHET MODEL PREDICTION

TABLE III CRUDE OIL PRICE AFTER FORECASTING USING PROPHET MODEL

Forecasting Crude Oil Price After 10 Years			
Date	**ŷ**	**Ŷ-Lower**	**Ŷ-upper**
29-09-2026	51.4711	25.7902	76.5831
30-09-2026	51.3547	24.7246	77.1518
01-10-2026	51.4748	26.1601	77.9832
02-10-2026	51.7234	25.1130	77.4300
03-10-2026	45.9649	19.4508	72.7055

As shown in Figure III, the Prophet model was combined with the Random Forest model to forecast crude oil prices for the next two years, using historical data dating back to 2019. Combining these models yields higher-accuracy results, as the Prophet model addresses long-term and seasonal trends, while the Random Forest model uses market behavior and sentiment analysis to fine-tune forecasts. The hybrid model used for analysis, as shown in the graph, represents actual data, the dark blue line represents the projected future price, and the light blue shaded areas show confidence intervals (dark shade = 80% confidence interval, lighter shade = 95% confidence interval). We can see from the model that the price of crude oil declined between 2019 and 2020 and bottomed out due to COVID-19, as the entire economy suffered a downturn. Then, from mid-2020 to mid-2022, the graph observes the price peaking above $120 as a result of post-pandemic and geopolitical events. We also observe price stability during the period 2023-2025. Finally, based on the forecasts, the model shows a decline in prices, with the lower bound projecting a drop to around $50-60 USD and the upper bound projecting a drop to $90-100 USD. This can be interpreted as a gradual price correction or a decline in global demand for oil.

As we can observe in Table III, it can be observed that the average forecasted price for each barrel falls around $50-52, showing a normal oil market. However, the prediction intervals show a wide range of prices that fall between $20 and $78, and that indicates a high level of uncertainty that may be due to the volatility of the global market of energy, and the geopolitical events.

V. CONCLUSION

This study shows a realistic finding based on Monte-Carlo simulation and a Hybrid FB Prophet-Random Forest model, both of which provide rich and distinct insights into crude oil price forecasting.

Related to Monte-Carlo Simulation, the model shows a high volatility inherent and stochastic behavior in crude oil prices, which in turn led to generating a broad span of predicted price paths affected by macroeconomic conditions, past fluctuations, and geopolitics. The multiple predicted price paths can be used to conduct a scenario analysis, which allows them to take into consideration all possible future events. On the other hand, the need for more structured and trend-oriented forecasts was satisfied through the hybrid Prophet–Random Forest model, which in its turn recognizes seasonal patterns on a long-term basis, while the nonlinearity and sentiment effects that may appear during the analysis were controlled through the Random-Forest model, which eventually generates accurate and interpretable predictions.

One of the most interesting outcomes in this research was that the hybrid model demonstrates that historical price behavior and seasonal events have a major role in shaping

future price patterns, as the crude oil price has structural trends and seasonal cycles. Meanwhile, the sensitivity of the crude oil price toward radical and sudden events was proven by the Monte-Carlo model, which in turn fosters the significance of modelling uncertainties in risky environments. By using both models in forecasting crude oil price, the forecast will be based on a comprehensive and complementary analytical framework, addressing both aspects: the accuracy and seasonality-based aspect related to the hybrid model, and the uncertainty analysis related to the Monte-Carlo simulation.

This study aims to provide value to investors, decision-makers, and ESG analysts. The results of the hybrid model are useful for investors because they provide long-term insights and thus contribute to more informed investment decisions. Meanwhile, the results of Monte Carlo simulations can be useful for risk management, as they quantify vulnerability to volatile market conditions.

In conclusion, future research must focus on studying more inputs to the model and then begin applying the model to other financial commodities, which will enhance the model's accuracy and predictive power.

VI. ACKNOWLEDGMENTS

We would like to deliver our big thanks to our university for their assistance throughout our academic journey. The support and enlightenment we received from our professors were very encouraging to us, which made us ambitious towards more research.

VII. REFERENCES

[1] Alquist, M. R., & Coibion, M. O. (2013). *The comovement in commodity prices: sources and implications*. International Monetary Fund.

[2] Cheng, Y., Yi, J., Yang, X., Lai, K. K., & Seco, L. (2022). A CEEMD-ARIMA-SVM model with structural breaks to forecast the crude oil prices linked with extreme events. *Soft Computing*, *26*(17), 8537.

[3] Wang, D., & Fang, T. (2022). Forecasting crude oil prices with a WT-FNN model. *Energies*, *15*(6), 1955.

[4] Mohammad, F. T., & Panigrahi, S. K. (2023, September). Forecasting Crude Oil Price Using SARIMAX Machine Learning Approach. In *2023 International Conference on Sustainable Islamic Business and Finance (SIBF)* (pp. 131-135). IEEE.

[5] Divyaa, S., Saravanane, R., & Kumar, M. (2024, April). Predicting Macro-Economic Factors of WTI Crude Oil Using Monte Carlo Simulation. In *2024 International Conference on Advances in Data Engineering and Intelligent Computing Systems (ADICS)* (pp. 1-7). IEEE.

[6] Ma, H. (2024, February). Research on Crude Oil Price Forecasting Technology Cased on Fbprophet. In *2023 International Conference on Data Science, Advanced Algorithm and Intelligent Computing (DAI 2023)* (pp. 260-269). Atlantis Press.

[7] Odu, A. T., Abubakar, B., Sulaimon, A., & Momoh, C. (2022). Modelling oil price volatility with structural break: A re-examination. *Odu, AT, Abubakar, BA, Sulaimon, AA & Momoh, C.(2022). Modelling Oil Price Volatility with Structural Breaks: A Re-Examination. West African Financial and Economic Review (WAFER)*, *22*(2).

[8] Kaymak, Ö. Ö., & Kaymak, Y. (2022). Prediction of crude oil prices in COVID-19 outbreak using real data. *Chaos, Solitons & Fractals*, *158*, 111990.

[9] Guo, L., Huang, X., Li, Y., & Li, H. (2023). Forecasting crude oil futures price using machine learning methods: Evidence from China. *Energy Economics*, *127*, 107089.