Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/JSTINP.2024.85841.1085
JSTINP 2024; Vol. 3, No. 1

Estimating the Potential of Changes in Oil Price in IPCC Climate Scenarios: A System Dynamics Approach

Kian Ebtekar[a], Hossein Khajehpour[a]*, Abbas Maleki[a]

[a] *Department of Energy Engineering, Sharif University of Tehran, Tehran, Iran.*

How to cite this article

Ebtekar, K., Khajehpour, H., Maleki, A., 2021. Estimating the Potential of Changes in Oil Price in IPCC Climate Scenarios: A System Dynamics Approach. *Journal of Systems Thinking in Practice*, *3*(1), pp.64-84. doi: 10.22067/JSTINP.2024.85841.1085.
URL: https://jstinp.um.ac.ir/article_44985.html.

A B S T R A C T

This paper uses the system dynamics approach to model the changes in oil price prospects in the framework of the shared socio-economic pathways (SSP) climate scenarios proposed by the Intergovernmental Panel on Climate Change (IPCC) until 2100. This theoretical structure connects the primary feedback mechanisms: supply, demand, and price. The determining factors of most tremendous significance in the supply sector are the Organisation of Petroleum Exporting Countries (OPEC) and non-OPEC production levels. The production targets set by OPEC are indicative of its market management policies and are significantly influenced by the actions of its key members. The oil price indicates a cyclical relationship with the oil supply of significant players. The determination of global oil demand in the demand section is based on various climate scenarios presented in the IPCC report. The fluctuation of Brent oil prices over time can be linked to the disparity between supply and demand. According to the model outcomes, the price of oil will be projected to decline to $20 per barrel by the year 2100 if the sustainability policies outlined in the SSP1 framework are implemented. However, in the alternative scenarios of SSP3, characterized by regional competition, and SSP4, characterized by heightened inequality and competition, oil prices are anticipated to rise to $100 per barrel. In the context of the SSP5 scenario, which posits a path of economic and social development reliant on the consumption of fossil fuels, the price of oil displays a declining pattern after a period of relatively higher prices. The peak oil prices within the Intergovernmental Panel on Climate Change (IPCC) scenarios exhibit significant variation based on their Representative Concentration Pathways (RCPs).

Keywords

Climatic change scenarios, Oil demand, Oil supply, Oil price, OPEC, System Dynamics.

Article history

Received: 2023-09-28
Revised: 2024-03-01
Accepted: 2024-03-04
Published (Online): 2024-03-19

Number of Figures: 9 **Number of Tables: 0** **Number of Pages: 23** **Number of References: 30**

****Corresponding author***
Email: khajehpour@sharif.edu

1. Introduction

Due to the concern of the world community about global warming, the efforts to adopt policies to manage the demand for fossil fuels, especially oil, have been expanded as one of the main factors of the aggravation of climate change (Meinshausen et al., 2009). A decrease in oil demand can cause a decrease in oil prices in a short time (Jaccard, 2005). As the prices of oil rise, the quantity of oil exploration operations leads to higher levels of greenhouse gas emissions (Harstad, 2012). Low oil prices are a barrier to production (Aghion et al., 2016). Many studies show that the transition from fossil fuel consumption to renewable energy is critical to reducing the impacts of climate change (Pörtner et al., 2022). The energy transition is predicted to lead to a long-term decline in oil demand, putting downward pressure on prices (Mercure et al., 2018).

The competitiveness and speed of adoption of alternative sustainable energy sources, such as electric vehicles, can be affected by oil prices. Rising costs associated with oil contribute to the increasing attractiveness of other clean energy sources. On the other hand, the decrease in the price of oil increases the continuous use of conventional fuels dependent on oil (Linn et al., 2014). If it has not happened yet, the peak of oil consumption may happen in the next two decades, subject to implementing policies to deal with climate change and sustainable energy developments (IEA, 2022). Finally, the relationship between oil prices and climate change influences the dynamics of supply, demand, and other oil market variables. (Pörtner et al., 2022).

In the international oil market, supply and demand are connected to determine the price while maintaining a state of equilibrium. Economic growth and development are the most influential forces behind increased demand for crude oil worldwide. According to studies, oil demand significantly correlates with GDP growth (Hamilton, 2014). Oil demand is more sensitive to oil price changes in the long run than in the short run because consumers need more time to react to changes in oil demand (Csereklyei et al., 2016). On the supply side, OPEC and key non-OPEC producers, such as Russia, have the market power to moderate global production and influence prices (Behar & Ritz, 2017). Finally, the imbalance between supply and demand causes oil price fluctuations. Faster demand growth than supply increases the price (Fagan, 2020). Overall, the interplay between changing supply and demand dynamics is a key determinant of global oil price changes, and understanding these fundamental market forces provides insight into the outlook for oil price changes (Baumeister and Kilian, 2016). This article uses the system dynamics approach to analyze the possibility of oil price changes in the

IPCC climate scenarios. System dynamics is a method for modeling and simulating complex systems and problems over time. It was developed in the 1950s by Jay Forster at the Massachusetts Institute of Technology. The key concept of this method is that systems can be modeled using feedback loops, state, and flow, which represent the non-linear dynamics of system (Forrester, 1968).

Because of the complexity of system dynamics models because of interdependencies, interactions, information feedback, and nonlinearity, testing different scenarios, policies, and decisions, the possibility of learning about complex systems through interactive simulations can be useful (Sterman, 2002). In system dynamics, a problem, such as oil price forecasting, is modeled as a system with state variables, flow, feedback loops, and nonlinearities. System dynamics is important for understanding oil price dynamics and making useful predictions.

Oil price changes under IPCC climate scenarios have been studied in this research. The Intergovernmental Panel on Climate Change published updated scenarios in the 2022 Sixth Assessment Report, Shared Socio-Economic Pathways. These scenarios provide frameworks for modeling different climate change mitigation pathways in this century (Pörtner et al., 2022).

Climate scenarios are divided into five categories in common social and economic path scenarios. In SSP1, sustainability policies support renewable energy, thus reducing oil demand. It puts pressure on the oil price. SSP2 reflects the middle path toward implementing climate policies and means a gradual reduction in oil consumption and relatively stable prices. SSP3 represents the spread of regional conflicts and nationalism, followed by increased oil demand and price. SSP4 shows high inequality within and between countries. Oil prices may fluctuate depending on economic instability. Under SSP5, oil consumption remains high due to fossil fuel development policies, keeping prices high (Behar and Ritz, 2017; Kikstra et al., 2022). However, the IPCC scenarios have limitations. These scenarios do not consider the short-term cycles, shocks, and structural failures that shape oil prices. In this research, according to the changes in oil demand in different climate scenarios, the outlook for oil changes has been evaluated as a system dynamics model (Riahi et al., 2017).

2. Literature review

Oil is one of the most essential commodities in the world, and fluctuations in oil prices have wide-ranging economic, geopolitical, and environmental effects. Therefore, predicting the prospect of accurate changes in oil prices is very important (IEA, 2022). However, due to the high dependence of oil prices on geopolitical events and the behavior of significant market players, it is tough to accurately predict oil changes in the long term. Of course, this has not caused different mathematical tools not to be used to model the behavior of oil prices. These models can be useful in many cases despite the simplifications considered. The literature review section attempts to provide a comprehensive literature review of modeling approaches to predict oil prices, especially climate policy scenarios.

Various quantitative and qualitative methods have been used to model and predict oil prices. These methods include system dynamics models, econometrics, computational simulation, statistics, machine learning, or multiple techniques. Each approach has relative strengths and weaknesses based on the representation of market structures, predictor variables, and basic assumptions. In the literature review section, the features and applications of these modeling approaches are evaluated with a focus on dynamic systems models.

System dynamics modeling is a method to understand the dynamic behavior of complex systems over time and provides nonlinear feedback relationships between variables in a system in the form of state, flow, and auxiliary variables (Sterman, 2002). System dynamics models are widely used to model the dynamics of the oil market and predict its price by using feedback loops between the key variables of supply, demand, inventory, capacity, and geopolitics to endogenously model the oil price (Mashayekhi, 2001; Rafiq et al., 2016; Samii and Teekasap, 2010). Greenman et al. (1994) integrated physical and economic factors affecting oil markets, such as resources, cost, technology, economic growth, and geopolitical issues. Hosseini et al. (2016) showed structural complexity in oil price dynamics using systemic models in his article. Rafieisakhai et al. (2016) evaluated the impact of different variables on market mechanisms by modeling the oil supply sector, including actors such as OPEC, non-OPEC, and American Shell Oil, and the demand, including sectors such as transportation and industry. Various studies have demonstrated the ability of system dynamics models to reproduce historical price, supply, and demand trends (De la Fe López-Domínguez et al., 2011; Rafieisakhaei et al., 2017). Hosseini et al. (2021) and Samii et al. (2010) argue that the integrated structure of system dynamics models can well represent the complex interactions between economic policies, technological changes, and market geopolitics. However, limitations, such as not considering some aspects of the real world, the need for computational resources in accurate and large models, and real-world simplifications in system dynamics models, make it difficult to accurately predict real oil price changes.

Econometric models estimate economic relationships and predict results using statistical methods. Many econometric techniques have been used to analyze and forecast oil prices, such as time series models, autoregression, sequential autoregression of random variables, and GARCH[1]. Econometric models use statistical methods of statistical estimation in a large set of data, mostly used for short-term price prediction in financial markets (Bashiri Behmiri and Pires Manso, 2013). However, econometric models are limited in representing structural complexities, feedback effects, and irregular events compared to simulation approaches and are highly dependent on the quality of input data.

Considering the limitations of system dynamics and econometric models, some models have developed hybrid models by combining system dynamics and econometric methods to predict oil prices. The main goal of developing these models is the simultaneous use of feedback loops and statistical estimation of econometric models and data analysis (Rafieisakhaei et al., 2017). These hybrid models increase the accuracy of predictive analysis compared to pure system dynamics or econometric approaches. The basis of system dynamics provides a strong theoretical framework that shows the interdependencies and dynamics inherent in the oil market. Econometric analysis strengthens the validity of the model using statistical methods. However, challenges in effectively integrating different approaches and their potential incompatibility still need to be addressed.

Large-scale computational simulation models have also been widely used by organizations such as the Energy Information Administration, the International Energy Agency, and OPEC to model global energy markets for policy forecasting and analysis. These models simulate the oil market and estimate prices based on accurate physics, technological, economic, and geological data with high computing power (Huntington et al., 2013). As an example, the global energy model of the International Energy Agency shows the economic interactions between demand, supply, prices, and other macro variables under various assumptions and limitations (Lee, 2021). These large computational models incorporate extensive data detail and represent multiple market actors and constraints. Their scale makes it possible to assess the precise effects of events and policies on sectors, regions, and stakeholder groups. However, their complexity can reduce model dynamics, make calibration challenging, and require extensive computational resources.

Beyond the dominant models, some studies have used alternative techniques to analyze and forecast oil prices, such as machine learning, gray, and factor-based models. Machine learning approaches such as artificial neural networks have been applied to detect nonlinear patterns in

[1] The generalized autoregressive conditional heteroskedasticity

oil price data (Bashiri Behmiri and Pires Manso, 2013; Xiong et al., 2013). While providing good complementary capabilities, these alternative methods have a weaker economic basis than other modeling methods.

In addition to quantitative modeling approaches, qualitative methods and experts' opinions have also been investigated in oil price forecasting processes. These approaches help to account for irregular factors such as geopolitical risks, technological innovations, consumer preferences, and environmental policies that are limited in quantitative modeling despite influencing the oil market (Huntington et al., 2013). However, quantitative models and historical data analysis are the primary inputs to forecasting prices. Qualitative inputs complement scenarios and uncertainties, and their unstructured nature makes integration into formal forecasting processes challenging.

A relatively comprehensive review of various modeling approaches for oil price forecasting and analysis has been presented. Different techniques have relative advantages and limitations, and no single model can fully represent the multifaceted complexities of oil market dynamics in the literature review section (Huntington et al., 2013).

3. Methodology

This study uses the system dynamics approach to determine and analyze the reaction of the global oil price to changes in its demand according to the scenarios of the International Panel on Climate Change, which was introduced in the sixth assessment report under the title of common socio-economic paths (Kikstra et al., 2022), provides a perspective of Brent oil price changes as one of the important indicators of the oil market. System dynamics provide a useful and practical framework for integrating the complex and non-linear relationships between key supply and demand factors and oil prices.

3.1. General model

The oil price outlook model is based on the fundamental analysis model developed in 2015 to check the balance of Brent oil prices as one of the main indicators of the oil market (Li, 2015). This model, developed and implemented in Vansim software, evaluates the equilibrium behavior of oil prices over time based on the balance between the oil supply and demand sectors according to the behavior of the main players in each sector. Figure 1 shows the causal loop diagram of the oil price analytical model.

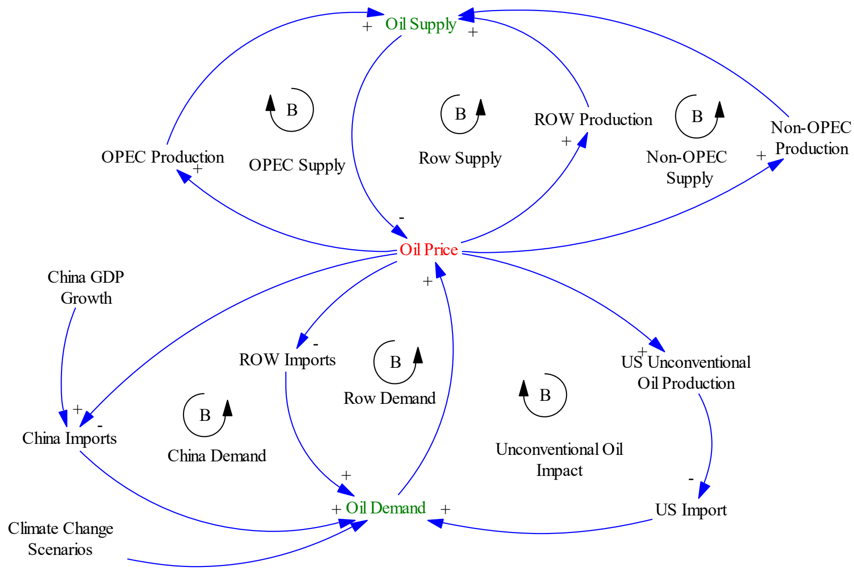

Figure 1. Causal loop diagram of oil price analysis model

As shown in Figure 1, this model models the main dynamics of the oil market in the form of nonlinear relationships by providing the structure of feedback loops, including demand, supply, and price. Key segments in the demand side include demand from China, the United States, and the rest of the world. In the supply sector, the amount of OPEC and non-OPEC oil supply has been introduced as determining variables in oil prices. In this model, the balance of supply and demand determines the price of oil, which affects the supply and demand of the main market players in a feedback loop. After developing the initial model, parameters are adjusted using historical data on oil production, demand, prices, and GDP from 2013 to 2022.

3.2. Demand subsection

The demand part of the model includes the demand of the United States of America and China as the largest oil consumers, and the demand of other countries in the world. The demand for oil in the United States of America is highly dependent on the price of oil due to unconventional oil production technology. Unconventional oil production technology requires higher oil prices so that the production process is economically justified. According to the oil price, the United States determines its demand based on the consumption and production rate of conventional and unconventional oil. The oil demand of China and other countries is increasingly correlated with the growth rate of their GDP. Other factors can also be effective in this model. Considering the demand parameters for the main players that are determined with the help of historical data, the impact of these factors has been simulated in the model. In this article, the oil demand section is determined based on the scenarios of the sixth assessment report of the IPCC, and the effect of the change in oil demand in climate scenarios on the oil price is evaluated.

3.3. Supply subsection

The supply part of the model includes the oil demand of OPEC, non-OPEC, and other world countries. The mutual relationship between the oil supply of each of the main players and the oil price is implemented in the model according to the historical data that determine the relationship between the oil price and the amount of production. In the supply sector, the model models the effect of these factors on the price of oil by considering a parameter that determines the impact of other factors affecting oil supply, which is obtained by calibrating the model with historical data.

3.4. Oil price

Finally, the price of Brent oil is modeled based on excess demand or supply in the entire global oil market. Excess demand puts pressure on prices. Meanwhile, excess supply pushes prices down. OPEC's behavior affects this balance by reducing or increasing production targets. The model uses econometric estimates of the historical relationship between oil inventory levels and prices to capture price dynamics.

3.5. Stock – flow diagram of the model

Figure 2 demonstrates that the oil market model contains several stock and flow diagrams affected by feedback loops of other variables. Oil Supply-Demand Disbalance represents the quantity of oil in surplus or deficit in the market. It is a critical stock in the system, directly affecting the Brent price level. OPEC Production Rate controls the amount of oil entering the system from OPEC countries. The non-OPEC Oil Production Rate represents the oil production from countries not part of OPEC. ROW Production Rate Stands for the Rest of the World and represents the oil production from the remaining global regions. Oil consumption is the outflow of oil consumed, determined by IPCC climate scenarios (Riahi et al., 2017).

Inventory Coverage is an auxiliary variable that affects Brent's price. It could represent how many days of consumption the current inventory levels can cover. Change in Brent Price is a variable influenced by the effect of inventory coverage on the price. It shows the directional change in Brent oil prices based on inventory levels.

A feedback loop connected the Change in Brent Price back to Inventory Coverage. which suggests that changes in the Brent price affect inventory coverage levels, further affecting the Brent price, showing a potential balancing feedback loop where the system tries to stabilize itself. Adjustment time represents the delay in the system before the effects of inventory coverage are seen on the Brent price. This variable can introduce a time lag in the price response to changes in inventory levels.

Table of Effect of Inventory Coverage on Brent Price as a table function determines how changes in inventory coverage affect Brent's price. It likely contains a set of values that define this relationship, which are used to calculate the effect on the Brent price based on the current level of inventory coverage. In order to create the table functions, the authors relied on data from the 2014 annual report of BP (Li, 2015).

The stock and flow diagram is a simplified representation of the oil market dynamics, focusing on the production side and its immediate effects on price levels. The central stock, Oil Supply-Demand Disbalance, is increased by OPEC, non-OPEC, and ROW production rates. It is decreased by consumption, representing the demand side. The Change in Brent Price is influenced by the Oil Supply-Demand Disbalance, which affects the Brent Price Level through the "Inventory Coverage. According to the model, the Brent price level is significantly determined by inventory coverage, which serves as a proxy for supply robustness. Including Adjustment time shows that the effect of inventory coverage on price does not occur instantaneously but after some time, reflecting real-world delays in market response.

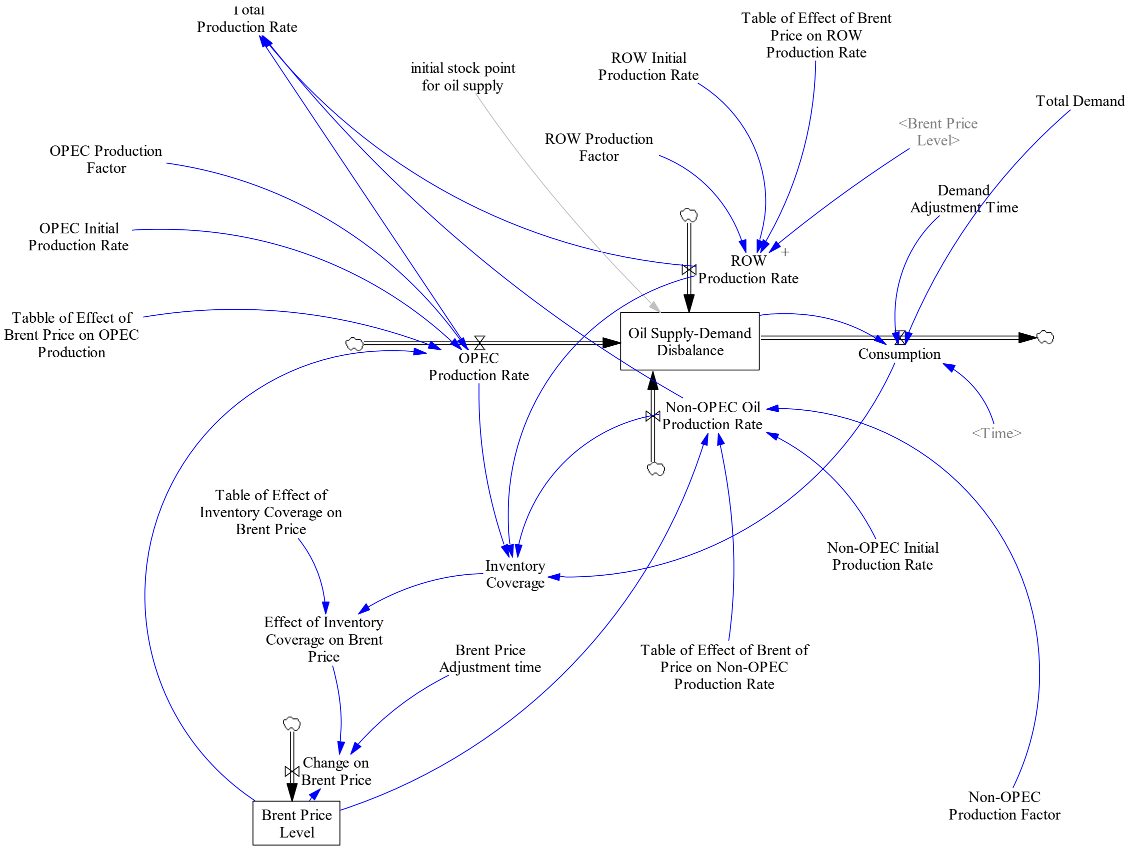

Figure 2. Stock - flow diagram of oil price model

4. Results and discussion

The model results predict a significant difference in the outlook for oil prices in different IPCC socio-economic pathways from 2013 to 2100. Figure 3 shows the assessment results of oil price changes under the SSP1 scenario and in different radiative forcing (RCP) scenarios.

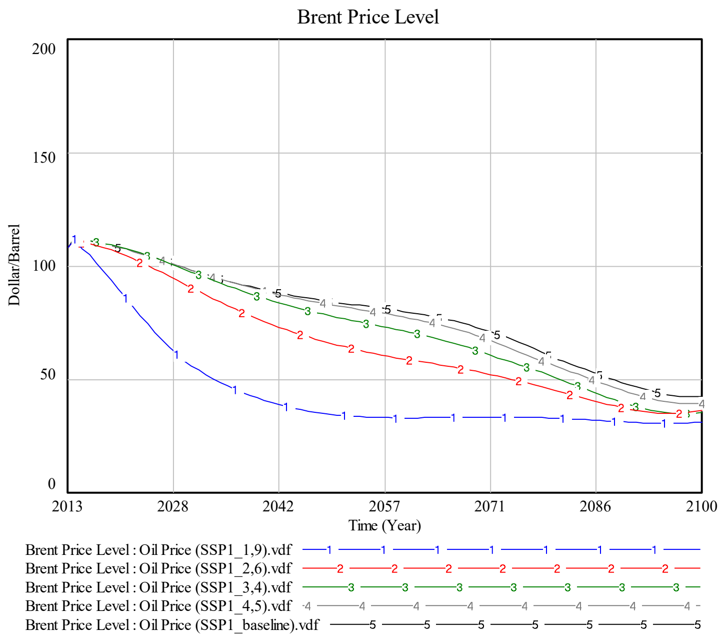

Figure 3. The assessment results of oil price change prospects under the SSP1 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

Figure 3 shows that under the SSP1 sustainability scenario, the average oil price in different forcing scenarios will steadily decline from around \$100/bbl in 2020 to around \$25-40/bbl by 2100. It indicates a significant decrease in demand for oil. Energy demand is shifting towards alternative fuels, and oil demand is decreasing. Of course, in different RCPs, this price reduction has different intensities. For example, in RCP equal to 1.9 watts per square meter, the intensity of oil price reduction is higher than in other scenarios. Figure 4 shows the results of assessing oil price changes under the SSP2 scenario and in different radiative forcing (RCP) scenarios.

 DOI: 10.22067/JSTINP.2024.85841.1085

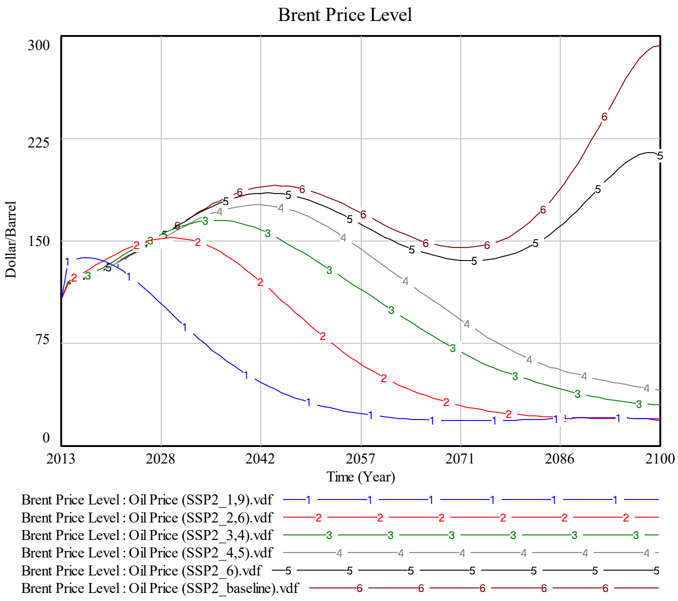

Figure 4. The assessment results of oil price change prospects under the SSP2 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

According to Figure 4, in the SSP2 scenario, which represents the middle path in climate scenarios, the reduction of oil prices depending on different RCPs can be different. In RCPs 1.9, 2.6, 3.4, and 4.5, since there is less strictness than in the SSP1 scenario, the amount of oil demand will peak after several years, and then the price of oil will start a downward trend after an upward period. Of course, the time to reach the peak of oil prices will differ in different RCPs. Figure 4 shows the results of assessing the outlook for oil price changes under the SSP1 scenario and in different radiative force (RCP) scenarios. Figure 5 shows the results of assessing oil price changes under the SSP3 scenario and in different radiative force (RCP) scenarios.

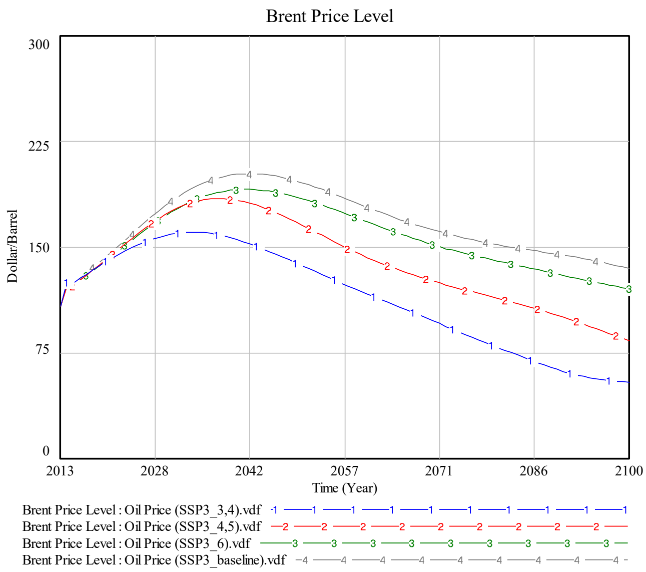

Figure 5. The assessment results of oil price change prospects under the SSP3 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

As shown in Figure 5, regional competition scenarios of SSP3 lead to sustained high oil demand and prices above $100 per barrel by 2100 in some RCPs. This scenario, defined based on regional competition, has fewer strictures to reduce oil consumption than the SSP2 scenario, which has caused the peak years of oil demand to have higher prices, which can have different rates in different RCPs. Figure 6 shows the assessment results of oil price changes under the SSP4 scenario and in different radiative force (RCP) scenarios.

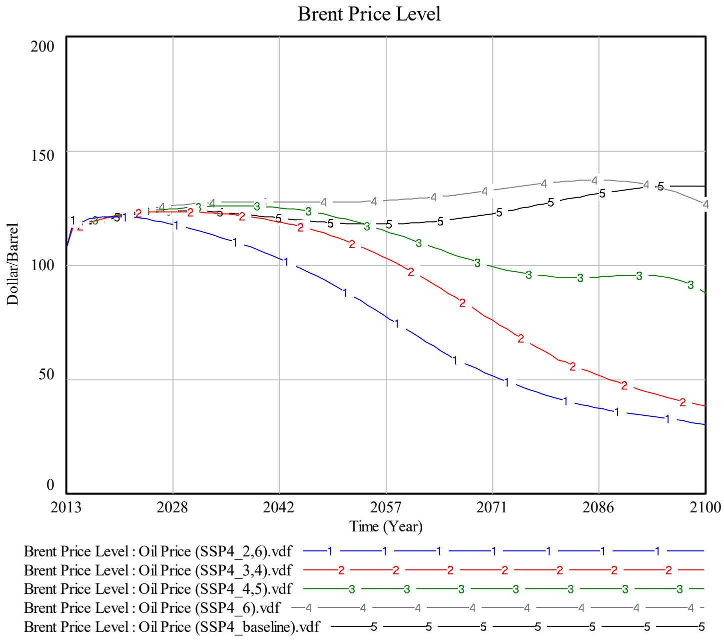

Figure 6. The assessment results of oil price change prospects under the SSP4 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

According to Figure 6, the SSP4 inequality scenario leads to oil price volatility with a generally increasing trend in some RCPs, which reaches about $80 per barrel by 2100. In this scenario, because of the formation of inequality and more intense competition compared to the SSP3 scenario, economic instability causes the progress in climate policies to be pursued in a more limited way. The amount of oil price changes in different RCPs can be decreasing, constant, or even increasing. Finally, Figure 7 shows the results of the assessment of oil price changes under the SSP5 scenario in different radiative forcing (RCP) scenarios.

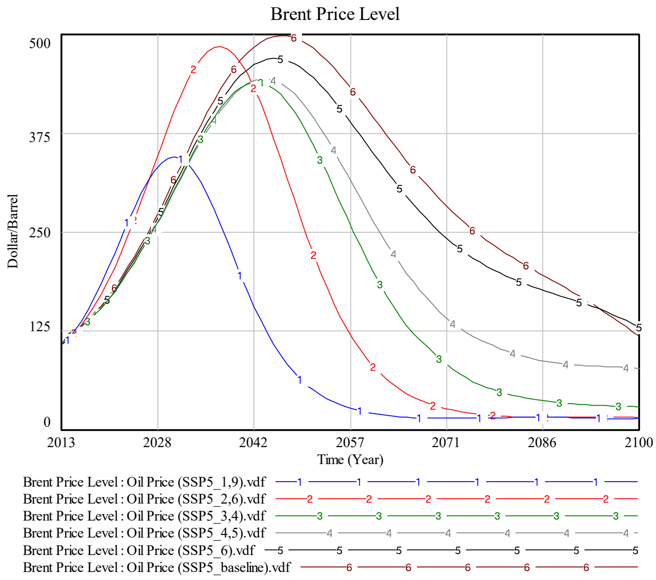

Figure 7. The assessment results of oil price change prospects under the SSP5 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

As shown in Figure 7, the SSP5 scenario, which is based on the growth and socio-economic development based on fossil fuel, predicts the growth of prices in the early years of modeling. Of course, this rate of increase in oil prices, following the reduction of supply compared to demand, after passing its peak, a trend will decrease sharply. This modeling highlights the risk of reducing the ratio of demand to supply in sustainability scenarios, in contrast to reducing supply and increasing prices under regional competition scenarios or scenarios based on economic growth with the priority of fossil fuel consumption. The timing of peak demand for oil varies significantly across scenarios, occurring around 2020 in SSP1 versus after 2100 in SSP3 and SSP5. It has profound consequences on the revenues and budget stability in oil-exporting countries and can directly or indirectly affect the economy of these countries in different sectors.

4.1. Model validation

To validate the model, the authors examine the Brent oil price prediction results in the IPCC climate scenarios with the oil price prediction in the International Energy Agency outlook report. The International Energy Agency has developed forecasts and scenarios to provide better insight into the adoption of policies related to the energy sector, and according to these scenarios, it has provided a forecast of oil price changes in the World Energy Outlook report. A scenario of announced commitments shows that all climate commitments made by governments worldwide will be fully and on time. Under this scenario, global greenhouse gas emissions peaked in the mid-2030s, but there is still a significant gap compared to what is needed to reach net zero emissions by 2050. The stated policy scenarios consider only the implementation of specific policies supported by law and have a high chance of implementation. Carbon dioxide emissions do not peak in this scenario but are inconsistent with achieving net zero emissions by 2050. The 2050 net-zero emissions scenario provides a tough but achievable path to net-zero emissions by 2050 for the energy sector. It requires the immediate and widespread deployment of all available clean and efficient energy technologies. By 2050, nearly 90 percent of electricity will come from renewables, with wind and solar accounting for roughly 70 percent. This scenario also depends on significant lifestyle changes based on reducing energy demand. Figure 8 compares oil price change prospects in IEA and IPCC climate scenarios until 2050.

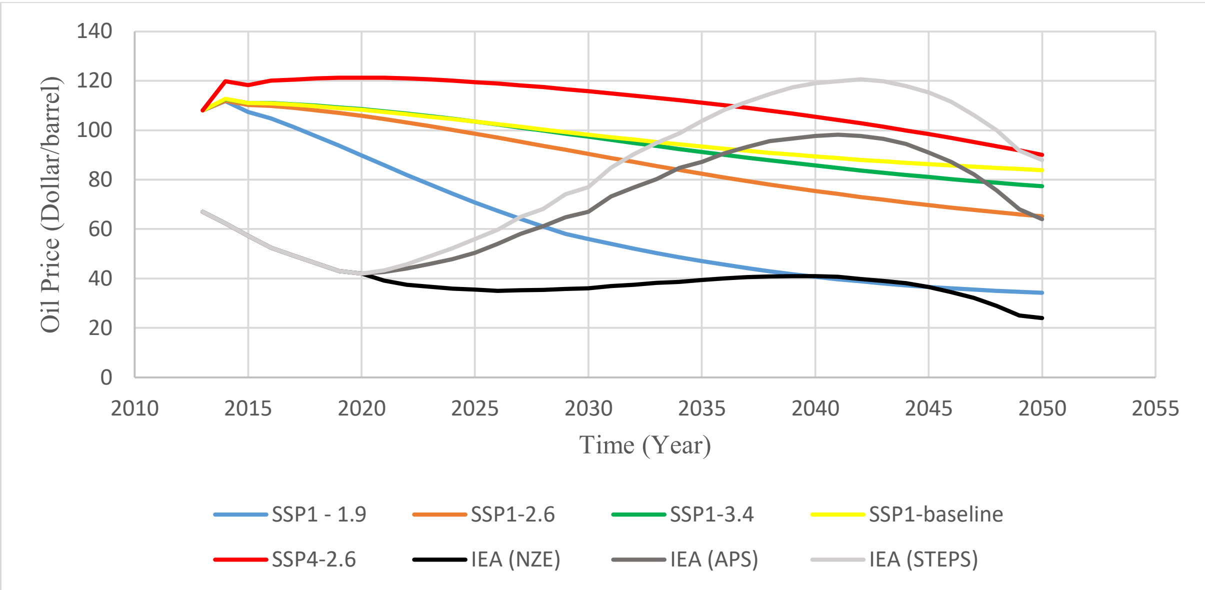

Figure 8. Comparison of prospects for oil price changes in the scenarios of the international energy agency and the climate scenarios of the IPCC

As shown in Figure 8, oil price changes in some IPCC climate scenarios are close to each other in different RCPs and IEA scenarios. Of course, since the International Energy Agency has evaluated the oil price based on the average price of oil importers, and also due to the very different definitions of scenarios, approaches, and the starting year of modeling in the International Energy Agency model, differences between the oil price forecast by the agency and there are research modeling results. However, a similar trend is observed in many scenarios. For example, the net zero emissions scenario follows a trend similar to the SSP1-1.9 scenario, which is a very strict scenario to reduce the consumption of fossil fuels, and the price of oil in 2050 is very close to each other in these two models. Also, the STEPS scenario indicates countries not meeting all their climate commitments and reports prices similar to the SSP4-2.6

scenario in 2050. Of course, as mentioned, due to the different nature of defining these scenarios and modeling methods, the results of price changes also differ.

The oil price model developed in this research reproduces the equilibrium price behavior based on oil supply and demand. The real price of oil can experience various fluctuations due to zeolitic events. In this model, parameters are considered to evaluate and determine the effects of these events. By calibrating the model and adjusting these parameters, the model can produce past behavior. Figure 9 shows the comparison between model results and historical oil price data.

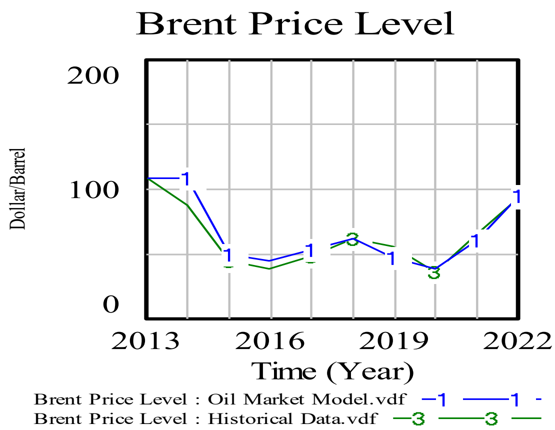

Figure 9. Comparison between model results and historical oil price data

As shown in Figure 9, the model has successfully reproduced the historical behavior of oil prices. The price of oil must change due to various factors. For example, after 2014, due to reasons such as the growth of American shale oil production, OPEC's policy change from price maintenance to market share maintenance, and economic growth slowdown, the price of oil decreased greatly due to excess supply (Prest, 2018). In this research, the main question is to examine oil price changes, focusing on the effects of climate scenarios on it.

5. Conclusions and suggestions

This system dynamics modeling approach integrates the complex interrelationships between drivers of oil supply and demand, geopolitics, climate policies, and economic growth. This model provides a useful framework for drawing oil futures contracts under various assumptions. Simulation analysis can inform industry strategies, investment decisions, and energy policy debates by mapping the outlook for uncertainties surrounding oil price forecasts. Further model development could include alternatives such as natural gas and electric vehicles, regional disaggregation, and game-theoretic aspects of OPEC's behavior.

 DOI: 10.22067/JSTINP.2024.85841.1085

The results emphasize the necessity of diversifying the economy and government revenues for oil-dependent countries. Excessive reliance on oil exposes countries to fluctuations in oil revenues. Strategic economic planning should pressure a wide range of oil price futures.

This modeling demonstrates the complex interplay between economic growth, climate policies, energy technologies, and geopolitics in shaping oil market trajectories. Short-term prices provide limited guidance on long-term trends. System dynamics models such as these can help inform robust, risk-informed strategies by public and private oil market players.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Attachment

Mathematical equations of the basic model for the evaluation of oil change prospects

Brent Price Adjustment time= 0.5
Units: Year

Brent Price Level= INTEG (Change on Brent Price, 108)
Units: Dollar/Barrel

Change on Brent Price= Brent Price Level*(Effect of Inventory Coverage on Brent Price-1)/Brent Price Adjustment time
Units: Dollar/(Barrel*Year)

China Demand= China Initial Demand*Effect of GDP Growth on China Demand*Effect of Brent Price on China Demand *China Demand Factor
Units: Barrel/Year

China Demand Factor= 1
Units: Dmnl

China GDP Growth= 7.7
Units: Dmnl

China Initial Demand= 3.92594e+09
Units: Barrel/Year

Consumption= "Oil Supply-Demand Disbalance"/Demand Adjustment Time+Total Demand
Units: Barrel/Year

Demand Adjustment Time= 1
Units: Year

Effect of Brent Price on China Demand= Table of Effect of Brent Price on China Demand(Brent Price Level)
Units: Dmnl

Effect of Brent Price on US Conventional Oil Production= IF THEN ELSE(Brent Price Level/US Conventional Oil Breakeven Price<1, 0 , Table of Effect of Brent Price on US Conventional Oil Production(Brent Price Level /US Conventional Oil Breakeven Price))
Units: Dmnl

Effect of Brent Price on US Unconventional Oil Production= IF THEN ELSE(Brent Price Level/US Unconventional Oil Breakeven Price<1, 0 , Table of Effect of Brent Price on US Unconventional Oil Production(Brent Price Level /US Unconventional Oil Breakeven Price))
Units: Dmnl

Effect of GDP Growth on China Demand= Table of Effect of GDP Growth on China Demand(China GDP Growth)
Units: Dmnl

Effect of Inventory Coverage on Brent Price= Table of Effect of Inventory Coverage on Brent Price(Inventory Coverage)
Units: Dmnl

FINAL TIME = 2022
Units: Year
The final time for the simulation.

initial stock point for oil supply=0
Units: Barrel

INITIAL TIME = 2013
Units: Year
The initial time for the simulation.

Initial US Conventional Oil Production Rate= 1.825e+09
Units: Barrel/Year

Initial US Oil Consumption Rate= 6.89375e+09
Units: Barrel/Year

Inventory Coverage= "Oil Supply-Demand Disbalance"/Consumption
Units: Year

"Non-OPEC Oil Production Rate"= "Table of Effect of Brent of Price on Non-OPEC Production Rate"(Brent Price Level)*"Non-OPEC Initial Production Rate"*"Non-OPEC Production Factor"
Units: Barrel/Year

"Oil Supply-Demand Disbalance"= INTEG ("Non-OPEC Oil Production Rate"+OPEC Production Rate+ROW Production Rate-Consumption, initial stock point for oil supply)
Units: Barrel/Year

Effect of Brent Price on ROW Demand= Table of Effect of Brent Price on ROW Demand(Brent Price Level)
Units: Dmnl

Effect of GDP Growth on ROW Demand= Table of Effect of GDP Growth on ROW Demand(ROW GDP Growth)
Units: Dmnl

Initial US Unconventional Oil Production= 1.82609e+09
Units: Barrel/Year

"Non-OPEC Initial Production Rate"= 9.51153e+09
Units: Barrel/Year

"Non-OPEC Production Factor"= 1
Units: Dmnl

OPEC Initial Production Rate=1.34426e+10
Units: Barrel/Year

 DOI: 10.22067/JSTINP.2024.85841.1085

OPEC Production Factor= 1
Units: Dmnl

OPEC Production Rate= Table of Effect of Brent Price on OPEC Production(Brent Price Level)*OPEC Initial Production Rate *OPEC Production Factor
Units: Barrel/Year

ROW Demand= ROW Initial Demand*Effect of Brent Price on ROW Demand*Effect of GDP Growth on ROW Demand*ROW Demand Factor
Units: Barrel/Year

ROW Demand Factor= 1
Units: Dmnl

ROW GDP Growth= 2
Units: Dmnl

ROW Initial Demand= 57111*365*1000
Units: Barrel/Year

ROW Initial Production Rate= 13863*365*1000
Units: Barrel/Year

ROW Production Factor= 1
Units: Dmnl

ROW Production Rate= Table of Effect of Brent Price on ROW Production Rate(Brent Price Level)*ROW Initial Production Rate*ROW Production Factor
Units: Barrel/Year

SAVEPER = TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

Table of Effect of Brent Price on OPEC Production([(10,0)-(250,1.1)], (10,0.1), (20,0.43), (30,0.7), (50,0.85), (60,0.92), (80,0.95),(108,1),(120,1.03),(130,1.05),(150,1.08),(250,1.1))
Units: Dmnl

"Table of Effect of Brent of Price on Non-OPEC Production Rate"([(10,0)-(250,1.01)], (10,0.2), (20,0.6), (30,0.93), (50,0.97), (60,0.98), (80,0.99),(108,1),(120,1.005),(130,1.01),(150,1.01),(250,1.01))
Units: Dmnl

Table of Effect of Brent Price on China Demand([(20,0.49)-(200,3.64)],(20,3.64),(40,2.02), (60,1.48), (80,1.21), (90,1.12),(108,1),(120,0.94),(140,0.82),(160,0.71),(180,0.6),(200,0.49))
Units: Dmnl

Table of Effect of Brent Price on ROW Demand([(20,0.49)-(200,3.64)],(20,3.64),(40,2.02), (60,1.48), (80,1.21), (90,1.12),(108,1),(120,0.94),(140,0.82),(160,0.71),(180,0.6),(200,0.49))
Units: Dmnl

Table of Effect of Brent Price on ROW Production Rate([(10,0.2)-(250,1.05)],(10,0.2),(20,0.5),(30,0.77), (50,0.87), (60,0.93),(80,0.98),(108,1),(120,1.01),(130,1.02),(150,1.03),(250,1.05))
Units: Dmnl

Table of Effect of Brent Price on US Conventional Oil Production([(1,0.5)-(10,4.5)],(1,0.5),(1.1,0.55), (1.2,0.6), (1.3,0.7), (1.5,0.8),(1.9,0.95),(2.16,1),(3,1.3),(5,2),(8,3.5),(10,4.5))
Units: Dmnl

Table of Effect of Brent Price on US Unconventional Oil Production([(1,0)-(10,6)], (1,0.3), (1.1,0.4), (1.2,0.5), (1.3,0.6),(1.5,0.75),(1.9,0.95),(2.16,1),(3,1.3),(5,2.5),(8,4.5),(10,6))

Units: Dmnl

Table of Effect of GDP Growth on China Demand([(0,0)-(20,2.6)],(0,0),(1,0.13),(2,0.26), (3,0.39), (4,0.52), (5,0.65), (6,0.78),(7.7,1),(8,1.04),(10,1.3),(20,2.6))
Units: Dmnl

Table of Effect of GDP Growth on ROW Demand([(0,0)-(10,5)],(0,0),(0.1,0.05),(0.2,0.1), (0.5,0.25), (0.8,0.4), (1,0.5),(1.5,0.78),(2,1),(4,2),(6,3),(10,5))
Units: Dmnl

Table of Effect of Inventory Coverage on Brent Price([(-50,0)-(50,30)], (-50,30), (-35.336,25.8571), (-23.3198,21.1429), (-14.1548,15.1429),(-10.2851,11),(-6.41548,7.71428),(-2.74949,3.71428),(-1,1.8),(0,1), (1,0.2),(5,0.15),(10,0.1),(15,0.05),(20,0.01),(50,0))
Units: Dmnl

TIME STEP = 1
Units: Year [0,?]
The time step for the simulation.

Total Demand= (US Demand+China Demand+ROW Demand)
Units: Barrel/Year

Total Production Rate= "Non-OPEC Oil Production Rate"+OPEC Production Rate+ROW Production Rate
Units: Barrel/Year

US Conventional Oil Breakeven Price= 50
Units: Dollar/Barrel

US Conventional Oil Production Rate= Initial US Conventional Oil Production Rate*Effect of Brent Price on US Conventional Oil Production*US Conventional Production Factor
Units: Barrel/Year

US Conventional Production Factor= 1
Units: Dmnl

US Demand= IF THEN ELSE(US Unconventional Oil Production rate+US Conventional Oil Production Rate -US Oil consumption Rate<0, ABS(US Unconventional Oil Production rate+US Conventional Oil Production Rate -US Oil consumption Rate), 0)
Units: Barrel/Year

US Oil Consumption Factor= 1
Units: Dmnl

US Oil consumption Rate= US Oil Consumption Factor*Initial US Oil Consumption Rate
Units: Barrel/Year

US Oil Inventory= INTEG (US Conventional Oil Production Rate+US Unconventional Oil Production Rate-US Oil consumption Rate,0)
Units: Barrel

US Unconventional Oil Breakeven Price=50
Units: Dollar/Barrel

US Unconventional Oil Production rate= Initial US Unconventional Oil Production*Effect of Brent Price on US Unconventional Oil Production *US Unconventional Production Factor
Units: Barrel/Year

US Unconventional Production Factor=1
Units: Dmnl

DOI: 10.22067/JSTINP.2024.85841.1085