OPEN ACCESS Freely available online

ISSN 2737-5331
Volume 1, Issue 2
https://www.iikii.com.sg/journal/IJBSI
International Journal of Business Studies and Innovation

Article

Structural econometric analysis of the covid-19 impacts on the worldwide petroleum market based on the evolutionary Amirkabir-De'es petroleum model

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Received: Aug 11, 2021; **Accepted:** Sep 11, 2021; **Published:** Dec 30, 2021

Abstract: Covid 19 disease has well demonstrated the expanse to which the health crisis can negatively affect the economic activities of petroleum-exporting countries. Experiential evidence confirms that worldwide petroleum prices and demand are two key channels for the disease to affect the economies of these countries. Due to the high significance of this issue, this study examines the effects of the Covid 19 disease on worldwide petroleum demand and the structure of the world petroleum market based on weekly data from Jun 14, 2000, to Jun 15, 2020. For this goal, the structural model of De'es et al. has been used, and the impact of this disease on the structure of demand and supply of petroleum in the short and long term has been studied. According to the results, it can be argued that Covid 19 disease from the worldwide crude petroleum price channel has a strong negative impact on the OPEC crude petroleum price index in the long run; Therefore, to avoid budget deficits and hyperinflation in OPEC countries, budgeting independent of petroleum revenues should be given serious attention by policymakers. Conventional petroleum models are not accurate in modeling global health crisis impacts on the oil market; the novelty of this paper is an evolutionary form of the De'es model of the petroleum market that can consider the demand-side shocks.

Keywords: Petroleum Industry, OPEC, Coronavirus, Covid-19, Oil Market, Oil Economics

1. Introduction

The global economic shock caused by the onset of Covid disease has well demonstrated that a health crisis can seriously affect economic activity. According to the International Monetary Fund (2020), the global economy is projected to shrink by 1% this year, even worse than the global economy during the 2008-2009 financial crisis. In this regard, it should be noted that the economic consequences of this epidemic depend on factors that are difficult to predict. These factors include the path of the epidemic, the intensity and effectiveness of efforts to control it, the extent of supply disruptions caused by the disease, the rate of contraction in the global financial market, changes in household spending patterns, and behavioral changes in individuals. Refusal to buy non-essential and durable goods and refusal to use public transport (uncertainty about the future and price fluctuations of goods; Foreign, is the reversal of capital flows and falling commodity prices) (WHO, 2020; Bahmanyar, Estebsari & Ernst, 2020).

Meanwhile, one of the key sectors that have been severely affected by this shock is the oil sector. In fact, following the deterioration of the outlook for the global economy and the disputes of oil-exporting countries, the decline in oil exports and its products has intensified. From mid-January to the end of March 2020, oil prices fell by 65% and natural gas prices by 38%. In addition, US oil inventories have increased, and stocks have been limited, while West Texas Intermediate crude has fallen about 75% (Mckibbin & Vines, 2020; Abu-Rayash & Dincer, 2020).

The world's major oil producers, led by the Organization of the Petroleum Exporting Countries and its allies, sought to stabilize the oil market as well as control inventories by announcing an agreement to cut oil production by 9.7 million barrels in early April 2020; However, this decrease in supply is not able to compensate for the increase in US inventories to 518.6 million barrels, and this has not been enough to compensate for the fall in demand and reduces oil prices. US crude futures prices also fell negatively for the first time in history as the contract expired (Norouzi, 2021). Thus, concerns have increased among investors and oil traders because traders preferred to sell the surplus oil in any way so that they would not have to store it; But evidence suggests that storage capacity at Cushing, Oklahoma, one of the largest storage tanks in the United States, for example, is steeply increasing (Santiago et al., 2021).

Stopping production, which can be very costly, or declaring economic bankruptcy by producers right now can be much less than paying tens of thousands of dollars to get rid of extra barrels of oil (Snow et al., 2020). Refineries receive much less input than usual, and as storage tanks are being replenished across the United States and globally, oil futures contracts will affect the market for months due to the severe oversupply of oil; So several million barrels of oil a day go to storage tanks, and some traders have rented ships to store oil (Norouzi et al., 2020).

In June 2020, about 160 million barrels of crude oil were stored in oil tankers during an unprecedented event, causing the largest monthly crude oil price difference in history (Norouzi & Fani, 2020). Also, oil investors have refused to renew their contracts at the expiration of their contracts due to a sharp decline in oil demand. Still, as futures contracts approach their expiration date, traders must decide whether to physically deliver their cargo or shift their position to another contract for the next month, so the oil price for delivery in the coming months is much cheaper. It will be delivered in the coming months, leading the market to strengthen the contingent structure, which indicates a surplus in the market (Zhang & Hamori, 2021).

Based on the empirical evidence obtained in recent months, it can be argued that Covid 19 disease has had serious negative consequences for the global oil market, which has caused serious damage to the world economy. Given the importance of this issue, we seek to answer the key question: through what channels does this unprecedented shock as an exogenous factor affect the global oil price index and oil demand? It is important to note that, in the current context, despite the oil sanctions over the past decade, the greatest losses due to the fall in oil prices to less than \$ 45 to the United States and major producers in the region such as Saudi Arabia, Iraq, UAE, and Kuwait, but in any case, the decline in world oil prices and the subsequent decline in Iranian crude oil prices, as well as the decline in Chinese oil demand from Iran (due to quarantine policy and restrictions on trade between countries), have severely affected this key sector in our country. It has created a serious economic crisis in the country (Razavi & Yazdi, 2020; Sharif, Aloui & Yarovaya, 2020). This article analyses the impacts associated with COVID-19 on international demand and supply for petroleum along these lines. Also, it worths mentioning that conventional petroleum models are not accurate in modeling global health crisis impacts on the oil market, and this paper presents an evolutionary form of the De'es model of the petroleum market.

1.1. Literature Review

COVID-19 begun in November 2019. Since then, great growth in daily infections and the collapse of health systems has taken worldwide attention. Later, in March 2020, it was declared a pandemic by the World Health Organization (WHO) (Zhang et al., 2020). Since then, the health situation has led various states to adopt restrictive mobility policies to contain the pandemic. Europe, after China, was one of the first areas massively affected by COVID-19. Thus, it was declared by the WHO as the worldwide center of the pandemic on Mar 13, 2020 (Weko et al., 2020). For example, in Italy, a national quarantine was decreed on Mar 9, limiting people's movement and allowing only mobility related to basic needs, such as health workers or other essential jobs. In Spain, a state of alarm was declared on Mar 14, but later (Mar 29), measures were tightened in response to the high contagion rates, forcing all non-workers to stay at home. Essential. The UK declared a quarantine status on Mar 23, shutting down all non-essential business activities along the same lines. This worldwide crisis hit the energy sector in every aspect and market, and the petroleum market was not exceptional. The hydrocarbon industry is one of the most important productive apparatus since it contributes to developing the national economy. According to official figures for 2018, calculated by IMF, this sector contributed 3.8% of the worldwide Gross Domestic Product (GDP) and is the largest collector of the selective consumption tax since it represents 40% of this concept[3].

A large number of Recent studies have analyzed the impact of COVID-19 on the petroleum market. These can be grouped into documents that i) describe variations in petroleum demand, ii) develop methodologies or statistic analyses that determine the impact of the pandemic on petroleum markets, iii) analyze the medium and long-term impacts of COVID-19 on petroleum markets, and iv) study the impact of the pandemic on industrial petroleum consumption according to its economic category.

The first group of descriptive studies is found [2], which analyses the impact of the distinct health policies applied in Europe to contain COVID-19. They exemplify six countries whose adopted measures have a distinct depth. In this way, countries with more restrictive policies such as Spain and Italy show large decreases in their consumption on working days, while in countries with softer measures, such as Sweden's case, it is observed that consumption has increased during the weekends. Likewise, in [4], they analyze variations in consumption in Ontario, distinguishing variations in demand patterns between pre and post-pandemics. Also, a recent review paper studied the petroleum and gas market in light of the Covid-19 impacts[5].

Reference [6] delves into the analysis of the Spanish case. For this, they analyze the decrease in demand, CO_2 emissions, and variations in prices considering the Spanish electrical energy system operator's data. In line with the above, in [7], they study the behavior of households in Australia. In this way, they identify that the increases in residential consumption are due to greater use of electronic devices and kitchen elements.

In the studies that develop methodologies to analyze the impacts of COVID-19 in the petroleum markets, it can be found that in [8, 9], a neural network is proposed to study the elasticity of demand for electricity and petroleum according to The percentage of people infected by the pandemic. In [10], the pandemic's effect on the petroleum demand in the United States is studied. One of the main challenges is that the consumption time series mixes the pandemic's effects with other effects such as climatic conditions. As a solution to this problem, it is proposed to apply regression models to separate the effect of climatic variables and thus be able to isolate the effects of the pandemic. This methodology is applied to Regional Utilities that have all the clients' information in their service area.

Another group of studies analyses the prospects in the petroleum markets. In [11], the impacts on demand are analyzed, highlighting a reduction in worldwide demand and increased residential demand. Besides, it explains the impacts on the generation market and the increase in renewable generation participation. Similarly, in [12], they analyze the short and long-term effects on the US market based on consumption at the national level. Thus, a decrease in CO2 emissions is expected in the short term because lower consumption has displaced generation from fossil fuels. However, in the long run, lower demand would reduce the incentives to invest in renewable technologies. Finally, [13] raises the opportunities associated with COVID-19 in the sustainable transition of regional petroleum markets.

Finally, other studies have analyzed petroleum demand variations in distinct industries according to their economic category. In the Latin market, in [14], the pandemic's impact on the petroleum consumption of distinct economic sectors is analyzed. Thus, it can be deduced that the sectors most affected have been the automotive, service, and textile industries, with drops in consumption of around 25%. In [15], the impact of COVID-19 in distinct economic sectors and the distinct Canadian provinces is analyzed, highlighting the impacts on the petroleum industry and its associated petroleum consumption. The vehicle manufacturing industry saw consumption declines of up to 60% in Ontario[15-18]. In Brief, the latest studies on the impact of COVID-19 on the petroleum market analyze how demand variations its consumption patterns, mainly from a systemic perspective[18-32].

2. Methodology

The petroleum shocks of the 1970s and 1980s led to theoretic advances in energy economics [6], many of which were used to model the world petroleum market. Standard structural energy models that simulated energy flows in physical terms remained important to international organizations [7, 8]. Still, most of the studies related to the price of petroleum conducted in the 1990s analyzed the links between petroleum prices and the macroeconomy—activity by applying new econometric techniques (for example, VAR and VECM models).

Recent increases in petroleum prices combined with, partly due to geopolitical pressures and high demand, have rekindled interest in structural explanations of petroleum price formation based on market equilibrium [2] which is standard practice models the world petroleum market in an equilibrium supply and demand schedule [4]. This approach has proven difficult due to the specifics of the petroleum market. Although a demand curve that relates quantities to prices can precisely represent the petroleum demand, modeling the supply is more difficult because petroleum is supplied by independent producers (non-members of the organization of the petroleum exporting countries (non-OPEC)) who act as takers－price and an organization (OPEC) that uses many factors to determine production levels and installed capacity. With variations in market conditions and organization of the petroleum exporting countries' behavior, these aspects of the petroleum exporting countries' production affect real petroleum prices [1].

We address these particularities with a quarterly model for the world petroleum market, including a pricing rule and demand and supply schedules for distinct world regions. To model supply, we distinguish between non-members of the organization of the petroleum exporting countries and members organization of the petroleum exporting countries production behaviors. Behavior outside the organization of the petroleum exporting countries is assumed to be competitive (but subject to geological and institutional constraints), while the organization of the petroleum exporting countries' production is modeled using various behaviors described in extensive literature [9]. Among the behaviors described, two can be identified as corner solutions: a cartel model, in which the organization of the petroleum exporting countries is the price maker, and a competitive model, in which the organization of the petroleum exporting countries is a price taker. Efforts to choose between these behaviors focus on identifying the petroleum exporting countries' supply curve slope. A negative relationship between price and production has been interpreted as a backward bending supply curve, indicating that the organization of the petroleum exporting countries sets production based on some non-competitive behavior. Econometric analyses of these relationships indicate that production by the individual organization of the petroleum exporting countries and OPEC as a whole "causes" petroleum prices, but prices generally do not "produce Granger output" [4]. More recent research indicates that individual organizations of petroleum exporting countries increase production in response to higher prices. Still, this response may be overwhelmed by variations in the organization of the petroleum exporting countries' quotas and production-sharing behaviors [11, 16]. In other words, the organization of the petroleum exporting countries works somewhere between the two corner solutions. To simulate this intermediate degree of "real world" control over the world petroleum market, the effect of market conditions and organization of the petroleum exporting countries' behavior on petroleum prices is often modeled with a "price rule." This rule gives the price at which the organization of the petroleum exporting countries operates ready to act as an oscillating producer, given the new demand conditions and market indicators that reflect the effect of the dominant producer's behavior. The existing model for worldwide crude petroleum consists of three blocks with equations for demand, supply, and prices (Figure 1). In this part, we present a general structure of the model, the details of econometric estimates are also described in the next part. This part does not describe the random structure of the model.

2.1. Petroleum demand

Petroleum demand equations for the ten major trading partners are estimated in the euro area; The United States, Japan, the United Kingdom, the Eurozone, Switzerland, other developed economies, non-Japanese Asia, developing economies, Latin America, etc. For each region, petroleum demand is a logarithmic-linear function of GDP, real petroleum prices, and time trends that provide technical variations, all of which affect energy efficiency. The general definition of econometric petroleum equations is as follows

$$DEM = \Phi\left(Y_i, \frac{POIL}{P_i^D} E_i, time, \zeta_i, \varepsilon_i\right) \tag{1}$$

In this equation, DEMi is equal to the demand for petroleum in physical units for each i region/sector, Yi is equal to the gross domestic product (GPD), POIL is the price of petroleum is in US dollars, Ei is the exchange rate in US dollars, P_i^D is also an indicator for domestic prices, ζ is the normalized petroleum derivative fuel demand, and ε is the uncertainty factor of the demand. All variables are logarithmic. As described in the estimation part, definition (1) reflects the determinants of long-term demand. Equation regression errors (1) are used to estimate error correction models in which latency effects and short-term variables determine quarterly variations in demand.

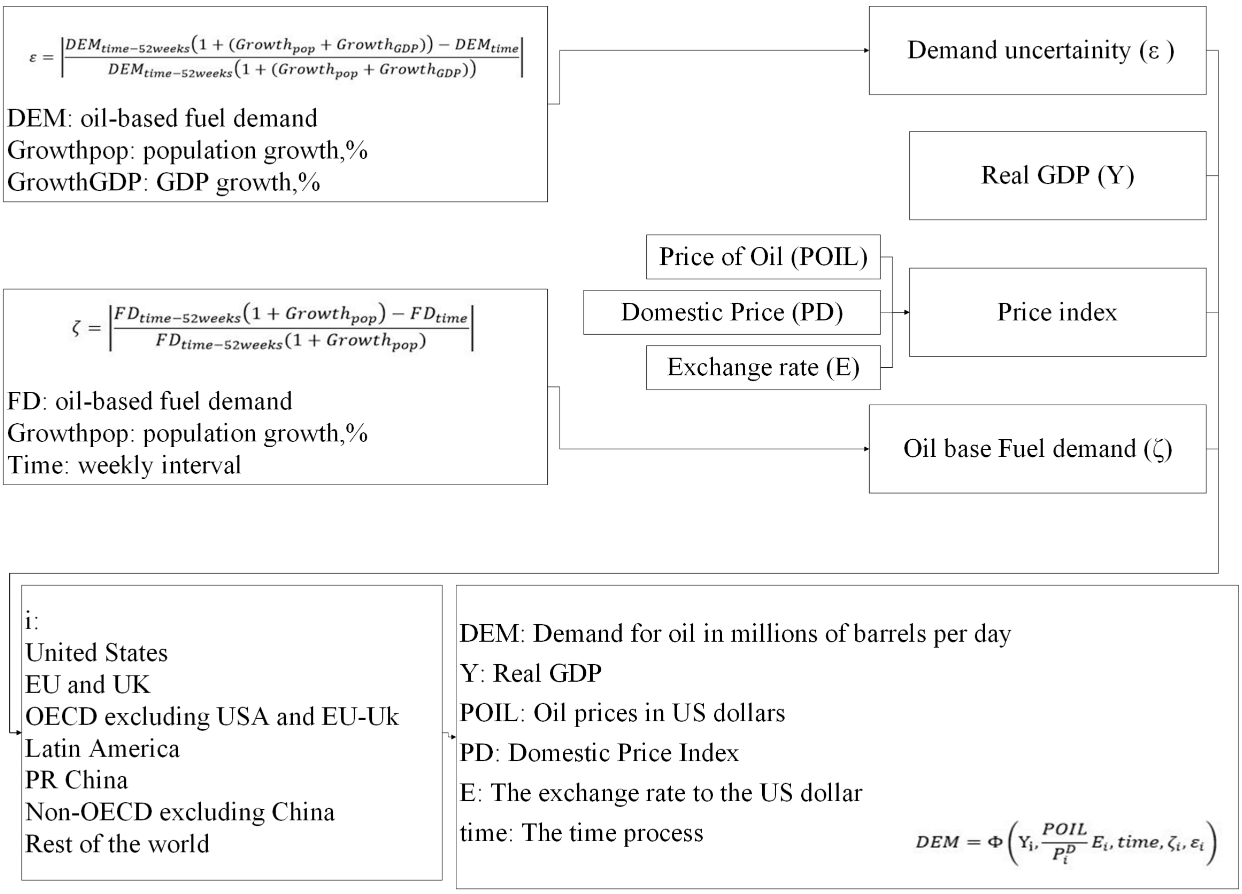


Fig. 1. Demand model of the petroleum market.

2.2. Petroleum supply

We distinguish between the organization of the petroleum exporting countries' supply behaviors and the non-organization of the petroleum exporting countries' nations. The first can be modeled using a participatory behavior in which the organization of the petroleum exporting countries adapts to demand-based production. It can be determined by a competitive behavior in which the organization of the petroleum exporting countries produces petroleum commensurate with its working capacity. Non- organization of the petroleum exporting countries' production has a considerable effect on the organization of the petroleum exporting countries' share of worldwide petroleum supply and, consequently, on the organization of the petroleum exporting countries' ability to influence prices. Production by the non-organization of the petroleum exporting countries is modeled using this method, which assumes that organizational and geological criteria constrain competitive behavior.

2.2.1. Supply OPEC

This model is designed to simulate two forms of organization of the petroleum exporting countries' production behavior: competitive and participatory production. Participatory behavior can describe the petroleum exporting countries' production from the third quarter of 1986 (Kaufman, 1995). During this period, the organization of the petroleum exporting countries devoted production to match the difference between worldwide petroleum demand and non-organization of the petroleum exporting countries' production. This behavior can be simulated with the following equation:

$$PROD^{opec} = \sum_i DEM_i + \Delta Stocks^{OECD} - NGLS - \sum_j PROD^{non-opec} - PG \tag{2}$$

In this equation, $\Delta \mathrm{Stocks}^{\mathrm{OECD}}$ is the stock level reported by the OECD, NGLS is equal to natural gas liquids, and PG is equal to the processing of petrochemical products.

In another way, the model can simulate competitive behavior by the organization of the petroleum exporting countries. Following this behavior, the organization of the petroleum exporting countries is competing among themselves and with non-organization of the petroleum exporting countries producers for market share. To compete for market share, the organization of the petroleum exporting countries increases production to compatible ratios with working capacity. To consider competitive production behaviors, the organization of the petroleum exporting countries production is simulated using the following equation:

$$PROD^{opec} = 0.95 Capacity^{opec} \tag{3}$$

In this equation, capacity is equal to the operable capacity of the organization of the petroleum exporting countries (millions of barrels per day). As described in the next part, the organization of the petroleum exporting countries' capacity is an external key factor. The competitive behavior described in the equation shows that production does not match demand. The petroleum produced is stored more than demand in warehouses, which, according to the price law described in the next part, will decrease the value of petroleum prices. When the model is simulated assuming the petroleum exporting countries' competitive behavior, the price law does not use the 95% application capacity ratio obtained in equation (3). Instead, the ratio of capacity consumption used in the price law is calculated based on the organization of the petroleum exporting countries' petroleum demand, given in equation (2).

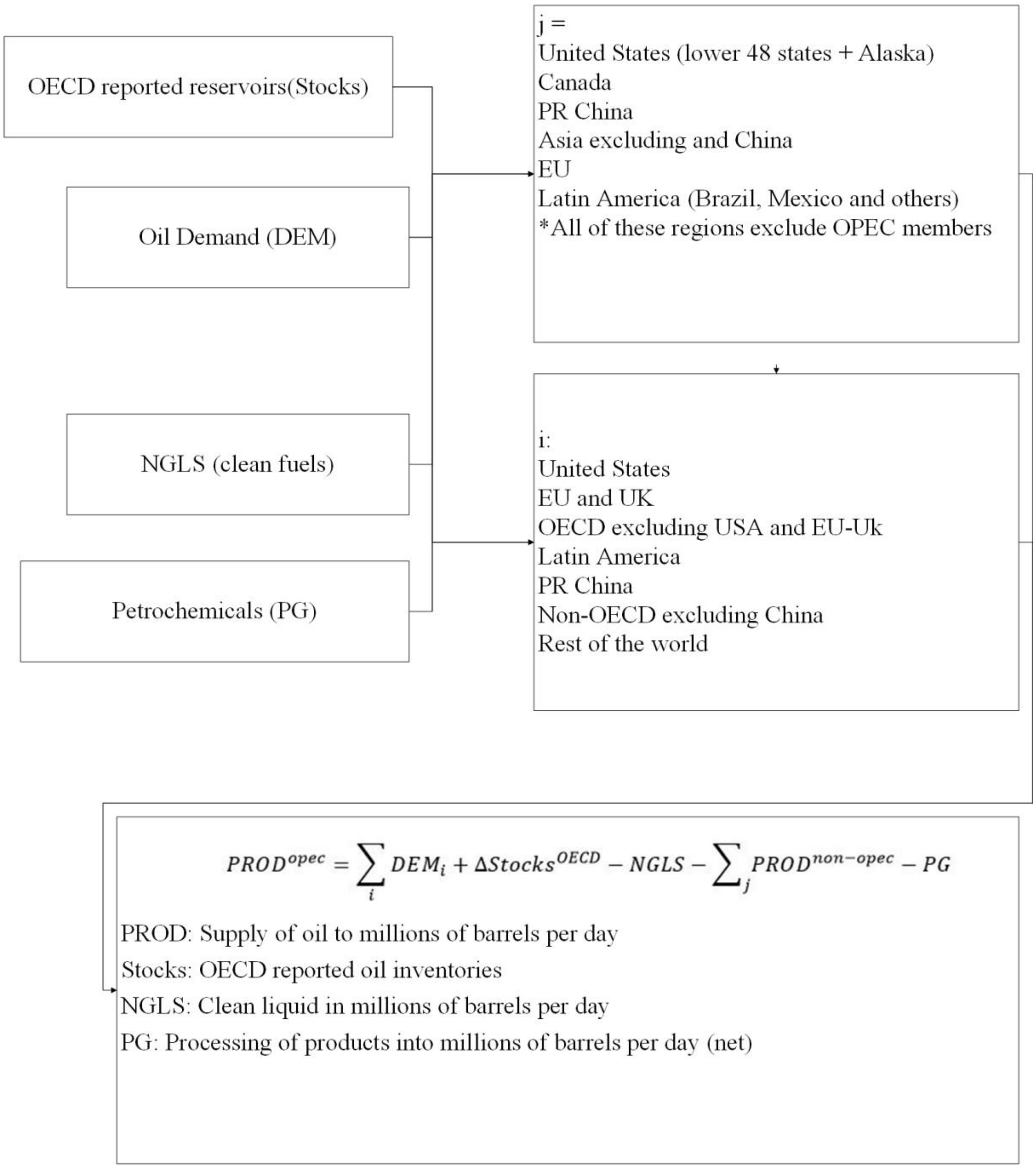


Fig. 2. organization of the petroleum exporting countries' supply model.

2.2.2. Non-OPEC supply

Although the most non-organization of the petroleum exporting countries' producers can be considered buyers or recipients of prices and maximum profit instruments, economic models of non-organization of the petroleum exporting countries' production are generally unreliable because there is no simple relationship between real petroleum prices and production [14]. For example, US petroleum production increased considerably between World War II and 1970, despite falling prices. In contrast, prices rose sharply between 1970 and 1985, but production declined.

Similar discrepancies were observed between price and production in the North Sea. These "differences" can be described in terms of resource imitation, technical change, economic incentives, and political differences; Therefore, these criteria should be considered to simulate petroleum production by the non-organization of the petroleum exporting countries. We will also describe the econometric method used to simulate the effect of geology, economics, and organizational metrics on the non-organization of the petroleum exporting countries' production in Part 3.

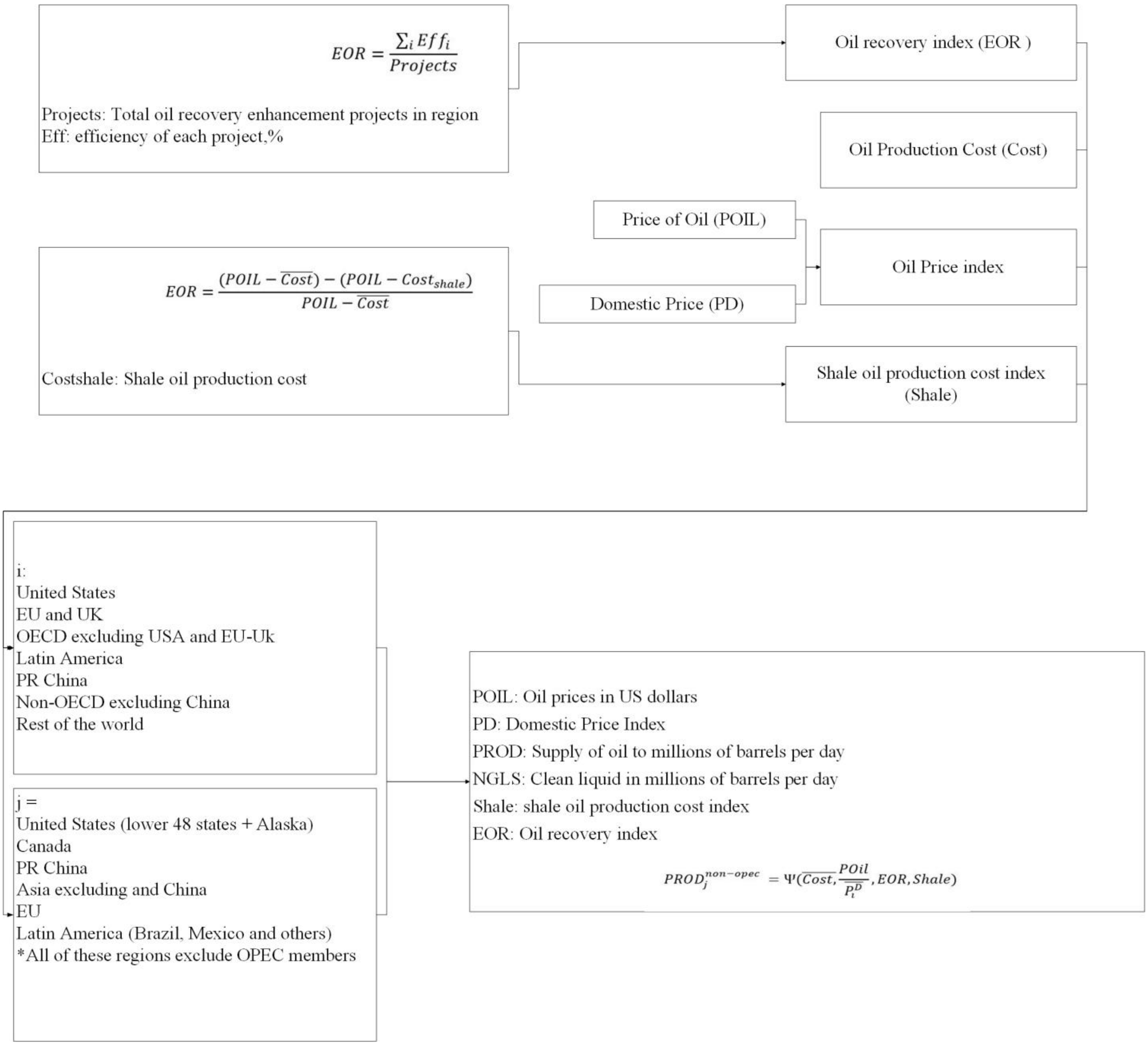
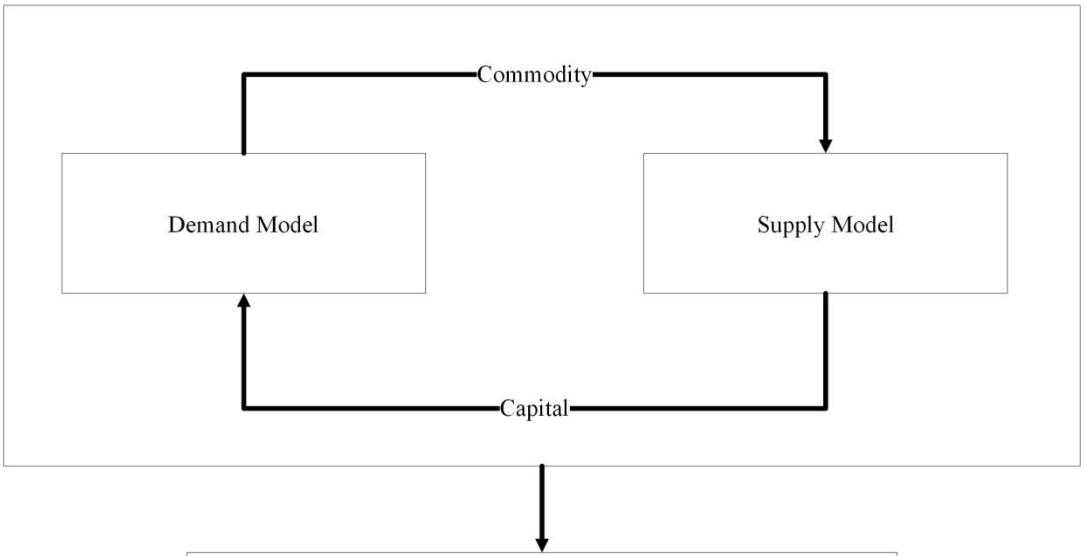


Fig. 3. Non- organization of the petroleum exporting countries' supply model.

2.3. Pricing model

It is difficult to model the real petroleum price due to an index producer and a high degree of sudden shock. With the advent of [12], various studies appraised the criteria for determining petroleum price. In addition to market metrics such as petroleum reserves, the behavior of the top producer is also an important factor in petroleum prices. Between the late 1930s and 1960s, the Texas Railroad Commission (TRC) became a leading producer by dividing Texas production into demand. This reduced the sudden shock in real petroleum prices. In the early 1970s, the organization of the petroleum exporting countries became the leading petroleum producer. The organization of the petroleum exporting countries has distinct policy guidelines than the TRC, and the sudden shock in prices has risen sharply. Howbeit it is easy to examine the effect of superior producer behavior on the sudden shock in petroleum prices [11], simulators find it difficult to simulate its effect for two reasons: (1) the inability to predict superior producer behavior; And (2) the inability to turn a particular behavior into a change in real petroleum prices[9].

As described in Part 1, the organization of the petroleum exporting countries' ability to influence petroleum prices depends on the ability of the petroleum union and the buyer's ability. Because no theory can describe this "intermediate behavior," experiential analyses have used a "price law" to simulate this intermediate degree, linking prices to the organization of the petroleum exporting countries' behavior measures and supply/demand balance market indicators[9]. The use of a price law to "solve" petroleum prices can be described as follows. At any given point, demand determines the quantity of petroleum supplied. Non- the organization of the petroleum exporting countries adapt their production to this new price, and the organization of the petroleum exporting countries is acting as an oscillating producer to balance supply and demand. The Price Act measures the expanse to which OPEC has developed to meet petroleum demand, and this measure measures capacity consumption and the ratio of production to shares. The Price Act also measures other market effects, including the level of reserves maintained in OECD nations. Together, these variables act as an intermediary for supply/demand, considering random trends in the historical record of real petroleum prices.



$$POIL = \Psi\left(\frac{\overline{Stocks}^{oecd}}{\sum_{i \in oecd} DEM_i}, \overline{Quota}^{opec}, \left(PROD^{opec} - \overline{Quota}^{opec}\right), \frac{PROD^{opec}}{\overline{Capacity}^{opec}} \right)$$

Quota: OPEC share in million barrels per day

Capacity: OPEC capacity in millions of barrels per day

Fig. 4. Petroleum market model and pricing law[1].

3. Petroleum model estimation

Before estimating, we use Dickey-Fuller figures to check for non-static (other than artificial variables) variables (see Appendix A for a complete view of the data set used). Because the outcomes show that the variables are extremely static, we also use the ordinary dynamic least squares (DOLS) estimate developed by [15] to estimate the integrated relationships. The reason for using this method is that it asymptotically generates optimal estimates of regression coefficients for integrating variables, is computationally simple, and performs better than other optimal and asymptotic estimators. The coefficients estimated by DOLS show a long-run relationship between the variables. We use OLS to estimate an error correction model (ECM) by examining short-term variables in the second step.

3.1. Demand

The estimation outcomes of equation (1) are presented in Tables 1 and 6a in Appendix B for more precise outcomes. A general definition of petroleum demand functions is provided in an error correction model. This model is estimated linearly logarithmically. Variables are created based on an econometric definition, and the estimation method identifies the long-term and short-term sensitivities of petroleum demand concerning real petroleum prices and revenues. We also provide superior models in terms of statistic significance and theory-predicted cues among all prior related definitions. The real price of petroleum does not enter into any long-term relationship. We also consider this variable in the dynamic expressions of ECMs. This is in line with Ruth's tests, which show that real petroleum prices - which show a high level of sudden shock - are stagnant.

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[1] Model closure This model closes based on OPEC behavior Collaboration [Equation (2)] or non-cooperation [Equation (3) + Remaining stock]

Except for Latin America, the coefficient associated with the error correction phrase for all countries/regions has a considerable zero difference. The significance of this phrase indicates that increasing the distribution between petroleum demand and revenue means more petroleum demand in the future, which pushes demand toward a long-run equilibrium imposed by a DOLS estimate to integrate the relationship. In all regions, income volatility is less than one, which causes petroleum demand to be uniformly adjusted to variations in income.

Table 6b provides distinct estimates for some countries using data on petroleum prices, including taxes. The reason for analyzing this data is that surgery accounts for a considerable portion of the final price; Therefore, the percentage of variations in petroleum prices observed by customers is much lower than the variations in crude petroleum prices. To assess this effect on econometric estimates for equation (1), we use a petroleum price scale calculated by the International Energy Agency and taxes for the United States, Japan, the United Kingdom, and Switzerland. Howbeit this definition ignores any alternative effect among energy products, it does meet the major criteria that affect petroleum demand.

Table 1. Outcomes of petroleum demand estimates.

	Matching ECM	**Period**	**Long-term**			**Short-term**			
			GDP Real	Trend	ζ	GDP Real	POIL[a]	ε	ζ
USA	0.66	2000:6–2020:6	0.96	-0.003	-0.02	0.75	-0.03	-0.06	-0.014
China	0.25	2000:6–2020:6	0.87	-0.003	-0.027	0.68	-0.04	-0.14	-0.019
EU-UK	0.80	2000:6–2020:6	0.56	-	-0.027	0.44	-0.04	-0.03	-0.019
Asia (without PRC)	0.33	2000:6–2020:6	0.75	-	-0.013	0.03	-0.02	-0.09	-0.01
OECD	0.81	2000:6–2020:6	0.38	-	-0.007	0.04	-0.01	-0.01	-0.005
non-OECD	0.07	2000:6–2020:6	0.50	-0.02	-0.013	0.05	-0.02	-0.17	-0.01
Latin America	0.23	2000:6–2020:6	0.83	-	-0.013	0.80	-0.02	-0.02	-0.01
Rest	0.50	2000:6–2020:6	0.57	-	-0.08	0.43	-0.12	-0.08	-0.058

The price of petroleum in national currency is balanced based on the domestic price index for each country. The CPI is used as an intermediary for the domestic price index. It can be shown that the outcomes obtained with CPI are more satisfactory than the types obtained with other domestic price intermediaries (GDP adjuster).

Comparing Tables 6a and b show that final consumer prices, unlike crude petroleum prices, do not cause a considerable change in the estimation outcomes.

3.2. Supply

Simulating the behaviors that determine OPEC production is relatively simple (see Part 2), but simulating a complex combination of economic, organizational, and geological criteria that affect non-OPEC production requires further investigation. To estimate the second component of petroleum supply, we update multiple methods developed by ref. [15-21] combines the Hubert curve bending method [22] with Fisher's econometric models [23]. Supply equations estimated from annual data and quarterly forecasts are generated by averaging annual values for this application. We also conclude that these interventions ignore annual maintenance patterns, but these errors have relatively little effect on price forecasting. This multiple method is estimated in three steps. In the first step, a logistic curve for cumulative petroleum production is estimated based on the method developed by Hubert. The logistics curve is also estimated using the following equation:

$$\ln\left(\frac{Q^{\infty}}{Q_{t-1}}\right) = \ln(a) + b(t - t_0) \tag{4}$$

In this equation, Q^{∞} is equal to the final and recoverable petroleum supply, Q_t is equal to the cumulative petroleum production at the time and equal to the start date of the analysis.

The first difference in the logistics curve shows the Hubert-shaped bell curve for the non-renewable resource production cycle, called the production curve. Using this curve, Hubert produced a very precise forecast for the peak in US petroleum production.

Subsequent analysis by ref [13] shows the basis for this success - the Hort bell curve is also an intermediary for the long-run, nonlinear petroleum cost curve.

Because the physical properties of petroleum fields do not fully determine production, multiple methods also involve economic and organizational variables. These effects are also considered in the second stage, in which the annual ratio of production based on the production curve (ΔQ_t) is used as a descriptive variable in the integration relationship for economic, geological, and organizational determinants, which are presented as follows:

$$\mathrm{PROD}_t = \alpha + \beta_1 \Delta Q_t + \beta_2 \mathrm{ROIL}_t + \beta_3 \mathrm{Local} + \beta_4 \mathrm{Asym} + \beta_5 \mathrm{Global} + \varepsilon_t \quad (5)$$

In this equation, PRODt is equal to petroleum production, ROIL is equal to the real petroleum price, Local is a discrete or continuous variable that affects local production (e.g., TRC segmentation in the United States (continuous), Peso crisis in Mexico (discrete)), Asym is a variable designed to test the assumption of symmetry that is not obvious in the production curve and Worldwide is am index for worldwide crises (such as Covid-19 which impacts the petroleum production). Asym Is a product of ΔQ_t and a fictitious variable that is equal to one after the peak of the production curve. Similarly, the Asym variable can be used for areas whose production has continued beyond the peak of the production curve. In the third step, the short-run variables of the supply equations are estimated using ECM, which has the following definition:

$$\Delta \mathrm{PROD}_t = \gamma + \delta_1 \mu_{t-1} + \sum_i \delta_2 \Delta Q_{t-i} + \sum_i \delta_3 \Delta \mathrm{ROIL}_{t-i} + \sum_i \delta_4 \Delta \mathrm{Asym} + \varepsilon_i \quad (6)$$

Table 2(a). Outcomes for equation (2).

	R^2	b	a	Q^{∞}	t_0
USA(Alasca)	0.93	-0.08	157.78	166600	1858
USA(without Alasca)	0.98	-0.21	426.59	14700	1948
Canada	0.94	-0.12	231.08	49000	1940
EU	0.98	-0.12	241.08	88200	1908
Asia non-OPEC	0.87	-0.09	177.58	65660	1877
Africa non-OPEC	0.98	-0.11	217.85	26460	1932
Latin America non-OPEC	0.98	-0.06	126.22	29400	1940
Mexico	0.69	-0.07	148.37	78400	1904
Brazil	0.84	-0.16	314.87	33320	1948

Table 2(b). Outcomes for the equation(3).

	ADF	R^2	Asym	Fabricated	EOR	Shale	Cost	$ROIL$	ΔQ_t
USA(Alaska)	-4.22	0.97	0.15 (10.66)		8.91(6.53)	-3.11(-6.51)		1.37 (2.68)	0.63 (23.34)
USA(without Alasca)	-4.83	0.98	-0.08(-3.59)	282098.5 (18.0)	116.41(8.74)	27.53(4.17)	-298.43(-12.3)	993.3 (2.72)	0.55 (20.27)
Canada	-1.24	0.86			15.12(10.13)	12.77(9.11)	-170.88(-7.11)	1.78 (2.46)	0.52 (10.34)
EU+UK	-3.42	0.93			4.81(5.18)			6.04 (4.73)	0.85(47.28)
Asia non-OPEC	-3.19	0.96						1.31 (2.68)	0.68 (53.18)
Africa non-OPEC	-4.27	0.95						0.85 (2.58)	1.05 (67.18)
Latin America non-OPEC	-4.21	0.95	0.39 (14.56)						0.95(53.95)
Mexico	-4.47	0.72		500.66(14.55)				7.19(9.72)	0.16(9.09)
Brazil	-4.08	0.91						0.78(2.26)	0.32(24.37)

In this equation, μ is the remainder in equation (6). Q^{∞} Quantity also provides the ratio by which petroleum production is adjusted for long-run equilibrium. The start date of the production curve and the amount of a priority are not known. Equations (4) - (6) are estimated using a range of values to identify these values, and the outcomes presented in Tables 2a and b are selected using the following criteria. First, a combination of and is chosen so that the remainder in equation (5) is static. This is done to identify the shape of the production curve integrated with the ECM production (and other variables) in equation (6) is considerable. From these combinations, we select the combination that has the highest R2. Equations (4) - (6) are also estimated for the nine non-organization of the petroleum exporting countries supply regions; 48 lower states (United States), Alaska (United States), Canada, Western Europe, non-organization of the petroleum exporting countries Asia, non-OPEC Africa, non-organization of the petroleum exporting countries South America except Brazil and Mexico.

The outcomes presented in Tables 2a and 2b show that the non-organization of the petroleum exporting countries' production is determined based on geological, economic, and organizational criteria. In general, the figures added by Dickey-Fuller show that geological, economic, and organizational criteria are the main cause of random trends in production. In addition, the signs in the variables are consistent with the theory - prices have a positive effect on production, while long-term costs harm production, as shown by the bell curve inverse. As an outcome, a combination of relationship integration and ECMs is considered for many historical variables in production, shown in a relatively large area.

3.3. Prices

As described in Part 2, the final equation of the model is a price law. Definition and estimation of law econometrics by ref. [13].

$$\mathrm{POIL}_t = \alpha + \beta_1\mathrm{DAYS} + \beta_2\mathrm{Quota}_t + \beta_3\mathrm{Cheat}_t + \beta_4\mathrm{Caputil}_t + \beta_5 Q_1 + \beta_6 Q_2 + \beta_7 Q_3 + \beta_8\mathrm{Cov} + \mu_t \tag{7}$$

In this equation, DAYS is the number of weeks of consumption of OECD crude petroleum reserves, Quota is equal to the share of organization of the petroleum exporting countries production, Cheat is equal to the difference between OPEC production and OPEC shares, Caputil is equal to the capacity consumption by, Q1, Q2, Q3 are also the fictitious variables for the first, second and third quarters. Cov is a fictitious variable for the Covid-19 pandemic (2019-2020).

The signs on the regression coefficients of equation (7) (Table 3) are consistent with the prior outcomes described by Razavi and Ahmadian (2020). The regression coefficient is negatively related - increasing inventories reduce real petroleum prices by reducing dependence on current production, thereby reducing risk, which depends on supply failure. Similarly, increasing the organization of the petroleum exporting countries' stocks tends to ease upward pressure on prices. An increase in the variable also tends to reduce the price - and an increase in organization of the petroleum exporting countries production relative to their stocks leads to an increase in supply relative to the demand received by the organization of the petroleum exporting countries when regulating stocks (demand may not be the most important or the only variable used to regulate stocks). The sign in the regression coefficient is positively related and is consistent with the sign described by Sharif et al. (2020) and Norouzi et al. (2020). A positive sign indicates that an increase in capacity consumption tends to increase prices. This work is consistent with the petroleum exporting countries' role as a marginal producer during 2000-2020. During this period, organization of the petroleum exporting countries generally adjusts production to match the difference between non-organization of the petroleum exporting countries supply, which is determined based on the non-organization of the petroleum exporting countries capacity (non-organization of the petroleum exporting countries producers acts as recipients generally at or near capacity and demand) and keep prices within a certain optimal range). As demand for petroleum from the organization of the petroleum exporting countries increases production relative to capacity, consumption also increases, indicating "cohesion" in the market. The Cov variable also harms prices - prices fell after the covid-19 taken over most western EU regions and North America, but this effect disappeared during the late third quarter of 2020, and it was found that the Covid-19 had little effect on worldwide petroleum supplies.

The ECM estimate outcomes show that prices do not immediately match the long-run relationship. The regression coefficient related to the error correction phase is negative and statistically considerable (Table 3). The error correction point estimate is -0.56, indicating that 56% of the imbalance between prices and the variables on the right in equation (7) has disappeared after a period of a few weeks. This outcome is consistent with equation (7) interpretation as an integration relation in which the variables on the right lead to a realistic petroleum price.

Table 3. Estimates of the price equation.

Variable	Coefficient
Days	-1.67(3.67)
Caputil	32.51(2.69)
Cheat	-2.12(2.96)

Table 3. *cont*

Quota	-2.09(2.66)
ECM	-0.64(2.44)

Note: The values in parentheses are t-digits that are calculated using the New-Hast (1987) estimator.

4. Appraise model features

4.1. Model performance prediction

To appraise the model's ability to simulate worldwide petroleum market behavior, we run simple dynamic and static predictions from 2000 to 2020 (Figure 5). We are not aware of any of the petroleum price models in the corresponding research related to this type of "backwardness," in this type of backwardness, the external variables are GPD, worldwide production of liquefied natural gas, and crude petroleum production by Russia and China and organization of the petroleum exporting countries capacity. For example, scenarios for international petroleum models implemented by Norouzi et al. [17] externalize prices. The simulation outcomes show that the model simulates real petroleum prices equally and precisely and following standard criteria. For example, fully dynamic simulations' mean square root error is less than 2.6% after a quarterly period, about 3.5% after one month, and slightly less than 4.8% after three months (Table 4). These errors are small compared to the sudden instabilities in real petroleum prices, which have a simple average of $ 46.1 per barrel and a variance of $ 12.5.

Based on these sudden instabilities due to Covid-19, the model performs better in some periods than in others. The model performs poorly in simulating price failures in the second half of 2019 and early 2020, which coincide with the Covid-19. In the second quarter of 2020, petroleum prices fell about 40 percent and were lower than the retrospective price of fully dynamic simulations conducted in most references. On the other hand, the model can simulate price recovery and the post-2020 uptrend in prices associated with the rising organization of the petroleum exporting countries' capacity consumption ratios and declining OECD reserves.

The precision of price simulation does not indicate that the model can predict petroleum prices precisely. However, retrospective outcomes show that the model can achieve variations in petroleum supply and demand that cause real petroleum prices to fluctuate over the past two decades. Similarly, the model can simulate how the market responds to distinct types of "external shocks" and variations in the petroleum exporting countries' behavior, regional and worldwide crises. Some of these scenarios are described below.

4.2. Petroleum price shock effect

To appraise the effect of petroleum prices on supply and demand, the model of external petroleum prices is simulated (for example, the petroleum price law is "deactivated"). The first scenario envisages a steady 50% increase in petroleum prices. A 50 percent increase in petroleum prices will reduce demand by as much as 3% in the long run (Figure 3). Higher prices also increase the non-organization of the petroleum exporting countries' production, howbeit responsiveness is low (non-organization of the petroleum exporting countries' production increases by 1.75% relative to baseline). These ratios are relatively small responses consistent with research findings and show that petroleum demand and supply fluctuate over an average period of three to five years.

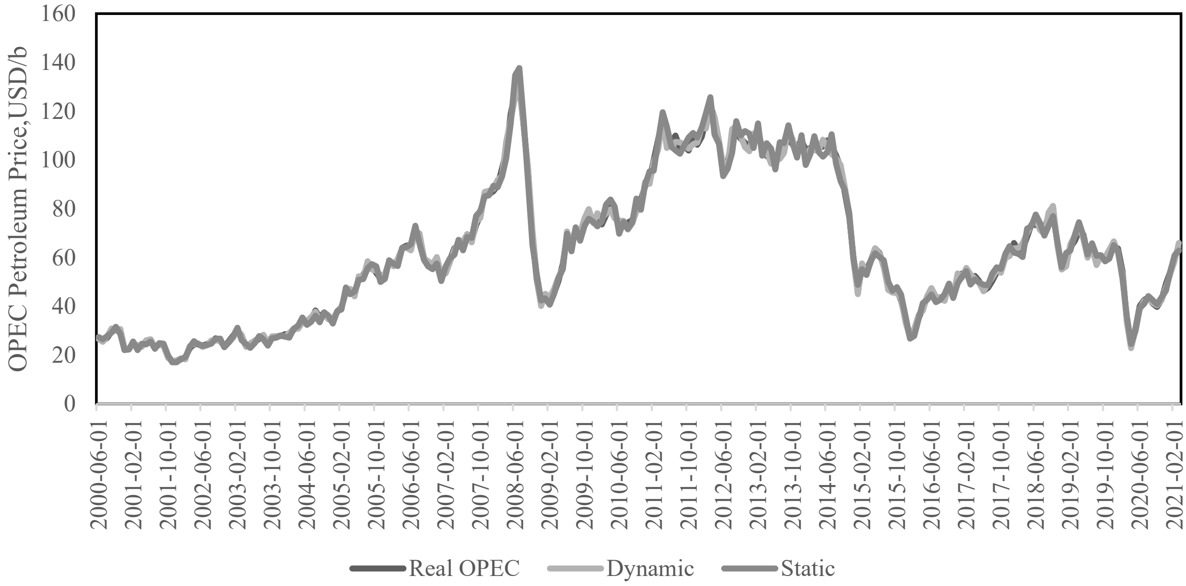

Fig. 5. Petroleum price $/bl, model and real maps.

Table 4. Performance Calculations Simple Performance Forecast for Petroleum Price (Square Average Root Errors in Percentage of Base Value).

Simulation	3month	2month	1month	weekly
Dynamic	4.99	3.65	2.52	1.87
Static	4.65	3.42	2.18	1.42

The cumulative response of non-organization of the petroleum exporting countries' supply is volatile; this response varies among non-organization of the petroleum exporting countries' regions (Figure 7). For most non-organization of the petroleum exporting countries regions, a 0.5 percent increase in real petroleum prices leads to a 1 percent increase in production. Two remarkable forecasts are Mexico and 48 US states, where higher prices will lead to a 5.5 percent increase in production. The relatively variable response is associated with an underdeveloped resource base and a considerable lack of capital in Mexico. Under these conditions, high petroleum prices could increase revenues and generate the capital needed to increase operational capacity (assuming the Mexican government returns the same revenues to PEMEX at the same rate as before in a sample period). In the United States, the relatively variable response is also associated with many small, independent producers willing to increase production responses to higher petroleum prices.

4.3. Covid-19 impacts on the petroleum industry

Figure 6 shows the short-term elasticity of the demand side in each region toward each key factor considered to model the petroleum demand. Outcomes show that the uncertain/external shocks of the demand side are the most effective negative factors that can cause the most considerable decrease in petroleum demand. But according to table 2, it is not a considerable player in the long-term models.

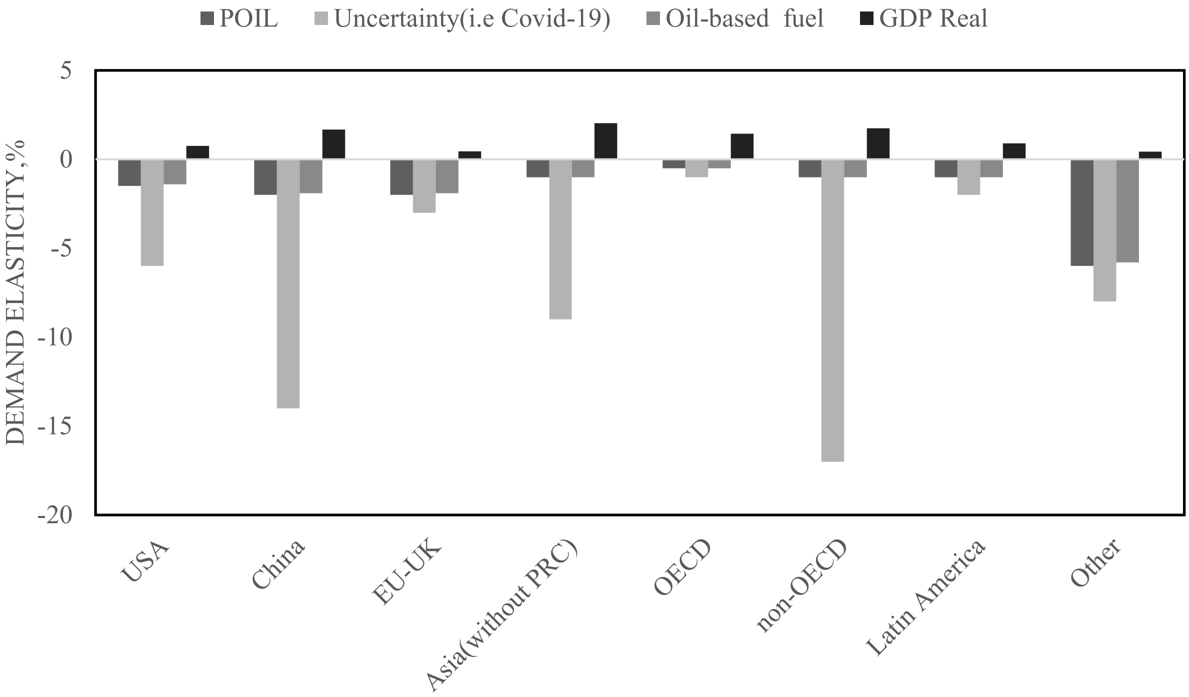

Fig. 6. Short-term petroleum demand elasticity toward main factors of the model.

Experiential evidence in recent months has shown that the Covid Crisis has had a considerable impact on countries' economies. Given the world's entry into recession, the need for government intervention policies to control the situation is increasingly felt. Of course, in the current situation, world countries are trying to adapt to the post-corona situation due to their capacities in the production sector. However, the economic shock caused by the Covid-19 crisis has had considerable negative effects on countries' economies, especially petroleum-exporting countries. These countries face a multi-layered crisis, including health shocks, domestic economic disruptions, a sharp drop in foreign demand, a reversal of capital flows, and falling petroleum prices. Also, the negative effects of this shock are amplified through some channels, such as the financial market, and have caused their economic flow to be reversed. In addition, declining worldwide demand has drastically reduced the price of goods, including petroleum, which puts financial pressure on exporters and has a detrimental effect on the economic activities of petroleum-producing countries. In addition, the downward trend in petroleum prices has also affected the decline in the worldwide financial market index, and there is evidence that in worldwide capital markets, the shares of individuals and legal entities are being sold at a rapid and low price turn worsens the situation. The economies of these countries are fueled.

In the current situation, the world economy is affected by negative pressures on the real sector in two ways: supply and demand. The world has faced the problem of the outbreak of the Covid-19 disease this year. Despite forecasts of increasing inflation in 2020 and a declining trend in fixed capital formation in the OPEC and other exporting countries' economies over the years, it was predicted that the worldwide economy would experience slight positive growth in the absence of this disease non-petroleum sector in 2021. Illness has plunged the world economy into recession with widespread uncertainty. The outcomes show that under distinct scenarios, between 1.5 and 3.3% of GDP will be reduced due to the spread of the virus. Also, 22 million employees lost their jobs due to the outbreak of the virus. Given the sharp decline in worldwide petroleum prices and the many prior links that the domestic economies, this issue indicates the deteriorating trend of the worldwide economy in the coming years.

In this study, considering the significance of worldwide petroleum prices and demand as the most important determinant of the worldwide petroleum market, the effects of Covid-19 disease on these two key variables have been investigated to make precise predictions of the situation. To this end, in this paper, the effect of the outbreak on worldwide demand for petroleum (as a negative indicator of worldwide petroleum demand as an indicator of worldwide petroleum prices), based on weekly data from June 14, 2000, to June 15, 2020, was examined. For this goal, the autoregression model with the De'es model approach has been used. The effect of the Covid-19 disease on petroleum demand and the specific petroleum price in both the short-term and long-term has been studied. They were demonstrating the specific impact of the Covid-19 on OPEC's crude petroleum price.

According to the current outcomes of this study, the Covid-19 disease has had a considerable negative impact on short-term petroleum demand and the petroleum price index. According to the outcomes of this test of causality, the existence of a strong indirect long-term causality is also confirmed (due to the covid-19 impact on the R&D investments in the petroleum industry) by the severity of the description of the world petroleum price, which is aligned to the Norouzi [5] and Zhang [13].

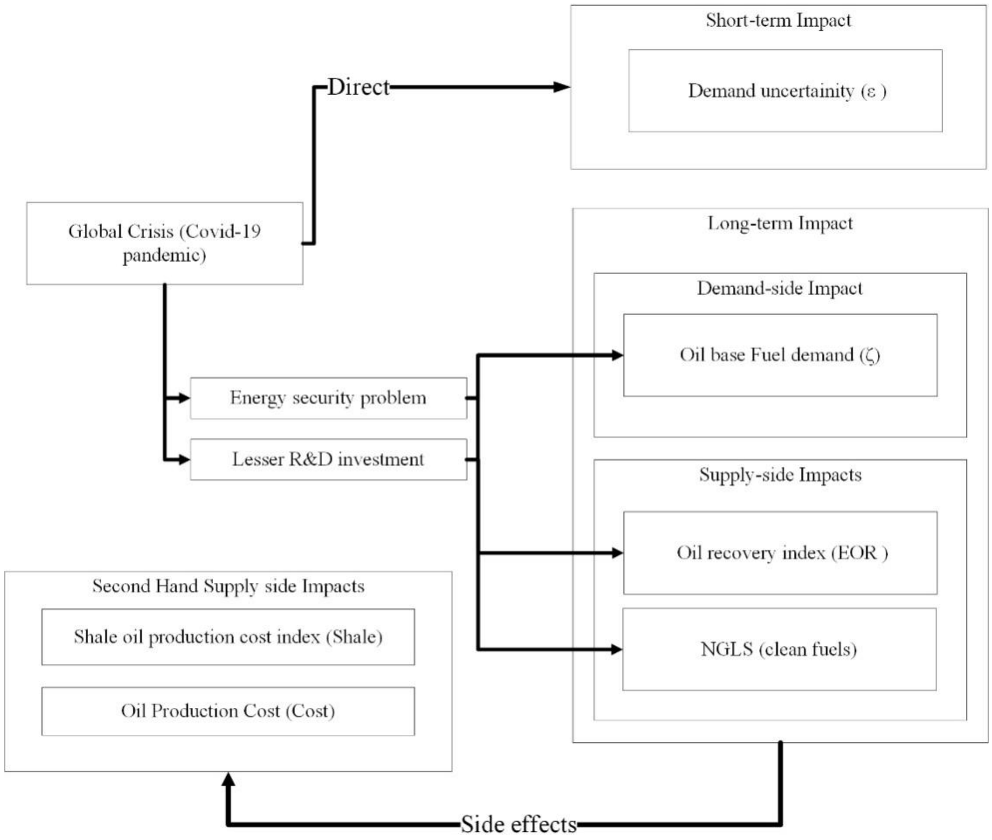

Fig. 7. Schematics of the Covid-19 impacts on the petroleum market.

Considering figure 7, we can calculate the direct and indirect impacts of the Covid-19 crisis on the petroleum market using a matrix of correlations and the autoregressive formulation of the cross-related impacts aligned with Norouzi [8, 9]. The Cross matrix outcomes are shown in table 5 below for distinct regions.

Table 5. Direct and indirect impacts of the Covid-19 impacts on the petroleum market.

	Ψ(ε)	Ψ(ζ)	Ψ(ε,EOR)	Ψ(ε,NGLS)	Ψ(ε,NGLS,EOR,Cost)	Ψ(ε,NGLS,EOR,Shale)
USA(Alaska)	-0.06	-0.02	0.33	-0.01	-0.12	-0.23
USA(without Alasca)	-0.14	-0.027	0.76	-0.01	-0.98	0.61
Canada	-0.03	-0.027	0.45	-0.01	-0.82	0.55
EU+UK	-0.09	-0.013	0.37	-0.01	-0.22	-
Asia non-OPEC	-0.04	-0.007	-	-0.01	-0.13	-
Africa non-OPEC	-0.17	-0.013	-	-0.01	-0.08	-
Latin America non-OPEC	-0.02	-0.013	-	-0.01	-0.09	-
Mexico	-0.08	-0.08	-	-0.04	-0.22	-
Brazil	-0.07	-0.05	-	-0.03	-0.13	-

4.4. Change in the organization of the petroleum exporting countries capacity

The decline in the petroleum exporting countries' organizations considerably affected the 1979 petroleum price shock. At that time, the Shah of Iran had fallen in the revolution, and Iran's capacity (and production) had been eliminated that year. An increase in the organization of the petroleum exporting countries' capacity is simulated to appraise the effects of the change in the petroleum exporting countries' capacity. By definition, this increase reduces the ratio of organization of the petroleum exporting countries' consumption capacity and thus reduces petroleum prices. Under the prior scenario, a change in capacity has no immediate effect on the petroleum exporting countries' production organization. Instead, the organization of the petroleum exporting countries' production variations responds to the immediate impact on petroleum prices. As shown in Figure 5, the reaction amplitude and its dynamic pattern are very similar to the prior simulation.

The decline in petroleum prices shown in Figure 5 may be why the oil-exporting countries' organization is reluctant to increase capacity (the oil-exporting countries' capacity in 2020 is necessarily the same as in 2005 and 1973). According to our simulation, an increase in capacity would immediately reduce real petroleum prices by as much as 12 percent and about 10 percent in the long run. The drop in prices will lead to a 2% increase in petroleum demand from the organization of the petroleum exporting countries. Taken together, these variations lead to the organization of the petroleum exporting countries' revenues falling by almost 8%. These reductions are consistent with the outcomes obtained by Bildirici [18] and Atri [19].

Lower incomes indicate that organization of the petroleum exporting countries is reluctant to add capacity to a time model. If your simulations are precise, the organization of the petroleum exporting countries should not increase capacity until petroleum demand has reached capacity and prices have risen. As an outcome, the organization of the petroleum exporting countries can use part of the surplus income to invest in capacity building. These additions then return the price to the prior capacity level caused by the price Shock. This variable could provide a "solution" for the high-cost environment of 2005 and 2012, resulting in high capacity consumption ratios. The petroleum exporting countries' organizations can use the increased revenue to increase capacity and lower prices.

The outcomes of the economic attractiveness of the organization of the petroleum exporting countries' capacity-generated simulations are contrasted with the National Energy Modeling System (NEMS) simulation hypothesis developed and maintained by the US Energy Sector. NEMS assumes that petroleum prices are external and uses these prices to calculate petroleum demand and non-organization of the petroleum exporting countries' production. This model assumes that the organization of the petroleum exporting countries increases capacity to balance supply and demand to balance supply and demand (as we did in equation (2)). But the association of this assumption with external petroleum prices eliminates the effect of capacity consumption on price, and as an outcome, models can make predictions that contradict the concepts expressed by the organization of the petroleum exporting countries' members. Also, this assumption assumes a regulatory nature for the organization of the petroleum exporting countries, which is not completely correct because the interests of the membering states mostly drive the organization of the petroleum exporting countries to act as a multi-national petroleum cartel [16, 20].

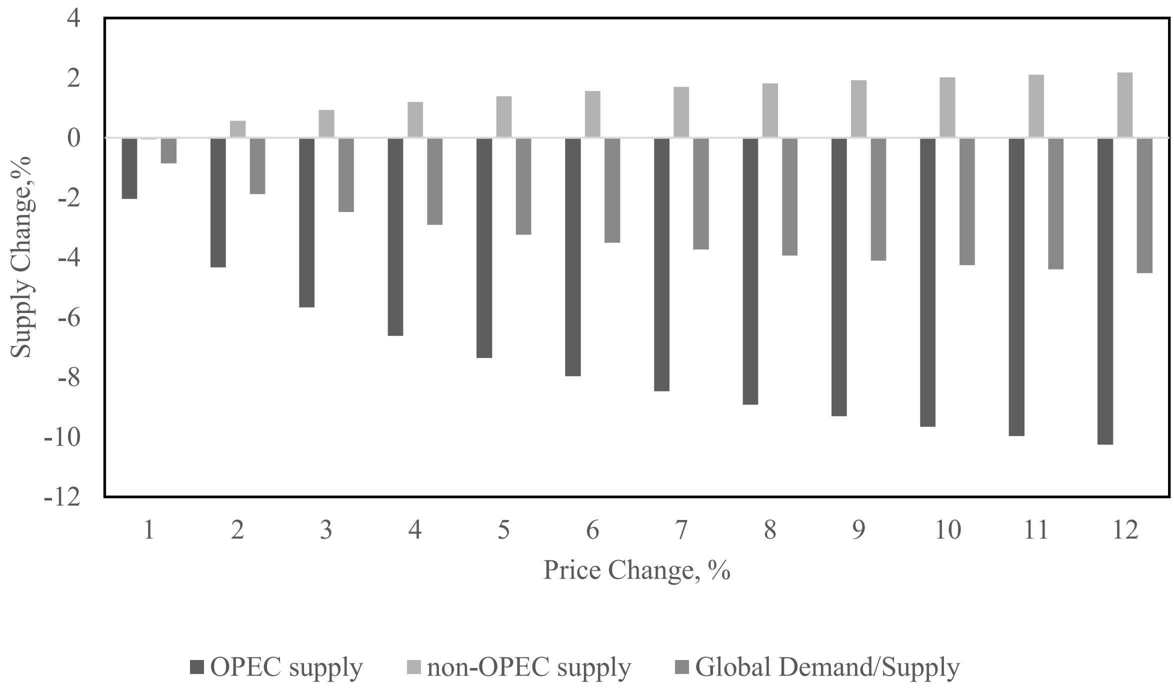

Fig. 8. Effect of increase in petroleum prices (external).

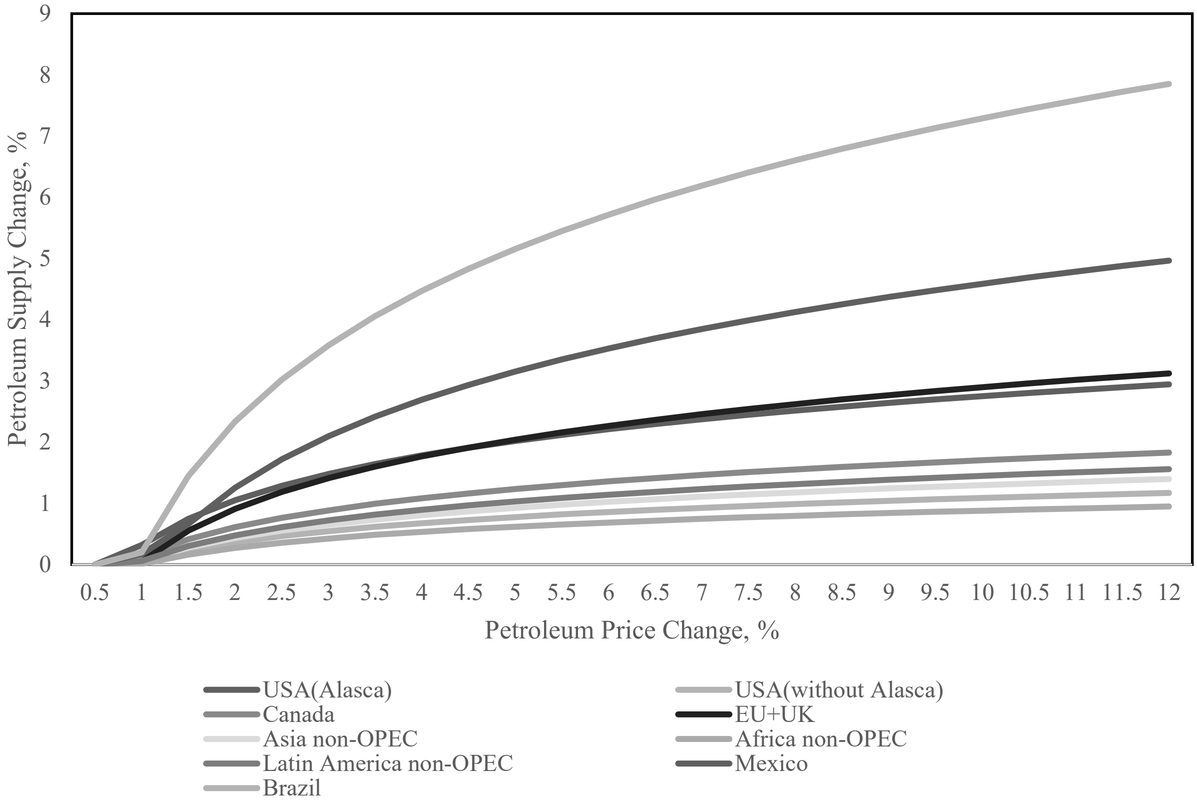

Fig. 9. Effect of increase in petroleum prices (external) on the petroleum supply.

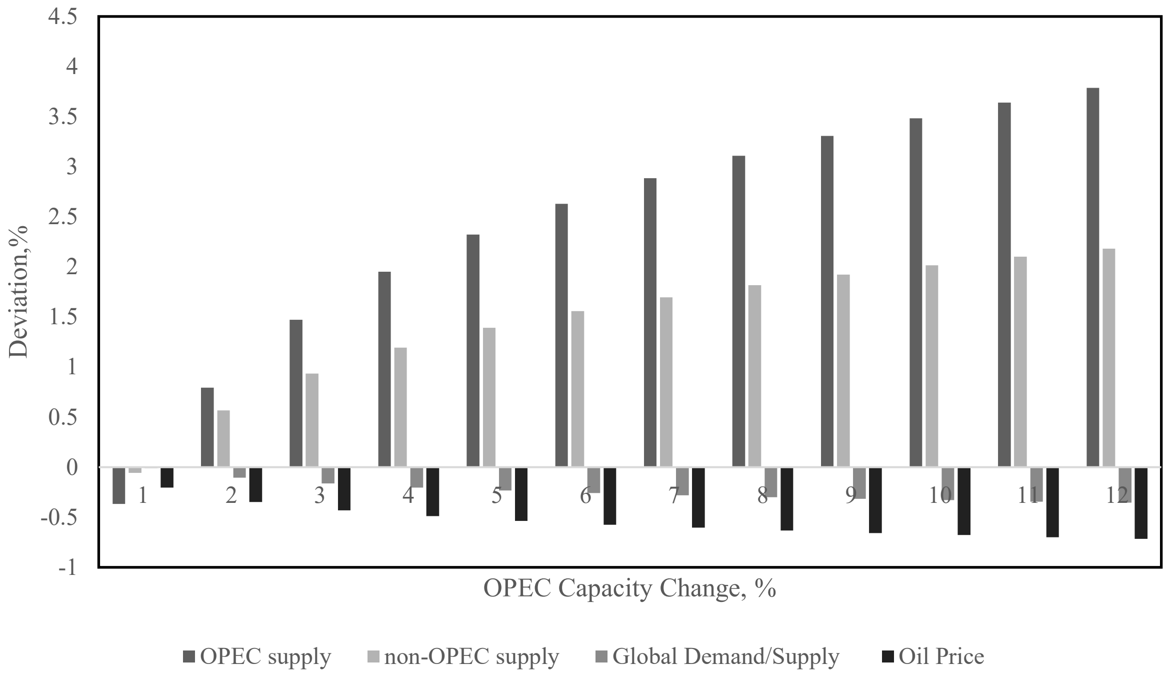

Fig. 10. Effect of increase in organization of the petroleum exporting For example, a recent NEMS simulation [21] predicts that the organization of the petroleum exporting countries will double crude petroleum production by 2025. A large part of this 100% increase comes from Saudi Arabia. But Saudi Arabia has frequently said it has no plans to increase production and bring it closer to NEMS forecast levels.

4.5. Shock OECD reserves

Wilkerson[21] argues that variations in inventory applications that have led to declining OECD crude petroleum inventories have contributed considerably to the overall increase in real petroleum prices since the late 2000s. To appraise the effect of variations on inventories, we simulate a stable 10% reduction in inventories. According to the DAYS-related regression coefficient sign in equation (4), a 10% decrease in inventories leads to a decrease in the number of days consumed, outcomes in an immediate 25% increase in petroleum prices, and a 35% increase after one year (Figure 8). Assuming that inventory decline is stable, this price increase will lead to a decrease in demand and an increase in non-OPEC supply, and as an outcome, petroleum demand from organizations of the petroleum exporting countries will decrease. These reductions also lead to lower prices, but the price decrease will be much less than the initial inventory reduction effect. Under these circumstances, a long-term decline in inventories has a stable and positive effect on real petroleum prices[33].

The Effect of Inventory Reduction on Price Emphasizes the initial discussion of Wilkerson[21] about the externality associated with maintaining inventory. People who hold stocks also avoid the risk of failure. But according to this simulation, maintaining inventories leads to lower real petroleum prices. This reduction also brings social benefits to OECD nations that extend beyond inventory conservation organizations. Similarly, private-level decisions about the optimal level deviate based on externalities, causing people to invest less in inventories. Based on the steady rise in real petroleum prices, this small investment could lose a considerable portion of overall social welfare. This suggests that policymakers need to develop intermediaries that increase individuals' willingness to conserve crude petroleum inventories (figures 9 and 10)[34, 35].

This paper describes a worldwide petroleum market model that can forecast petroleum supply, demand, and real prices and analyze the risks of each. The model simulates petroleum demand with behavioral equations that link demand to domestic economic activity and real petroleum prices. Supplying petroleum to non-organization of the petroleum exporting countries producers is simulated on the assumption that geological and organizational criteria constrain a competitive behavior. Actual petroleum prices are also simulated using the "price law," which shows the effects of market conditions and the behavior of the main player in this organization of the petroleum exporting countries model. Organization of the petroleum exporting countries' behavior can be simulated using two modes, a participatory behavior that ensures a balance between supply and demand and competitive behavior that uses legislation that simulates early petrochemical economies. The simulations show that the model can be used to understand the reactions of the worldwide petroleum market to various types of shocks and variations in the petroleum exporting countries' behavior and local and international catastrophes. For example, the scenario describing the effect of variations in the organization of the petroleum exporting countries' capacity points to economic reasons that organizations of petroleum exporting countries are reluctant to increase capacity. The scenario that simulates a shock to OECD inventories demonstrates the external significance of private decisions by considering optimal inventory levels. It also examines another Covid 19 shock scenario and calculates its effects on supply and demand and, ultimately, prices. It can be concluded that Covid 19 has two types of effects on the petroleum market, one short-term that affects the market supply and the other long-term effects on the supply side, which occur due to variations in long-term R&D investments and cause There is a sharp decline in petroleum supply in non-organization of the petroleum exporting countries. Also, with a closer look at energy systems, it can be concluded that this indirect investment change can affect the demand of countries, especially non-petroleum countries, in the long run, because these countries due to instability in The timing of petroleum shocks and the loss of petroleum competitiveness due to reduced development capital tend to shift to alternative fuels such as liquefied petroleum gas, hydrogen, electricity, etc., all of which reduce petroleum consumption in the long run. As an outcome, the model can create a dynamic and relatively precise price "regression" based on variations in petroleum demand and supply, leading to fluctuations in real petroleum prices over the past two decades.

Funding: This research did not receive external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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