Environmental Science and Pollution Research (2020) 27:19304–19313
https://doi.org/10.1007/s11356-020-08419-7

RESEARCH ARTICLE

Optimal oil stockpiling, peak oil, and general equilibrium: case study of South Asia (oil importers) and Middle East (oil supplier)

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Received: 14 January 2020 / Accepted: 12 March 2020 / Published online: 24 March 2020

Abstract
Optimal stockpiling is the best possible strategy to overcome the problem of peak oil periods of oil producer economies. We measured the properties of strategic petroleum oil reserve and general equilibrium and its peak oil effects. Measured the optimized scales of SPR through using oil price model, global oil market, and depletion effects of oil production classification. The peak oil period occurs from the interection between the geological era, proficiency in a practical skill, economy of consumers, and geopolitics, and the quality of deciding of demand and supply in which we have done a general dynamic balance model. Results reveal that peak oil time periods may lead towards diverse oil prices time profiles, economic development, and commodity flows. Interestingly, the macroeconomic effects of peak oil and the trajectories in objective function of two options maximize the households' welfare and oil revenues and its effect on growth trajectories of oil-consuming countries. If an oil supply disruption happens, the rate of oil acquisition will be considerably decreased, though it may not be a good strategy to interrupt the activities of oil reserve with the aim of minimizing the overall costs.

Keywords Optimal stockpiling · Peak oil · General equilibrium · Oil importer · Oil exporter

Introduction

South Asia accommodates approximately 25% of the world's population. There is a growing energy demand in highly condensed populated areas of South Asia, and since crude oil is the major contributor for energy generation in the region, oil consumption in South Asia is expected to grow by about 6% in the coming years. In particular, more than 140% enhancement in India's energy demand is expected in the coming years as compared to a 55% increase in the world (Kumar Singh 2013). Additionally, the oil reserves in the region are not uniformly distributed, where India holds the highest oil reserves of 5700 million barrels of crude oil compared to Pakistan and Sri Lanka with 324 million and 150 million barrels, respectively. However, the current oil reserves are insufficient to satisfy the demand of a population of approximately 2 billion (Mohsin et al. 2018b). South Asia's oil demand currently exceeds 29 million barrels/day. In this context, oil consumption at the current rate will cause a depletion in the next 30 years (Kumar Singh 2013). Although crude oil is the major contributor in the energy mix, the region lacks domestic oil reserves. Due to this impediment, the region is largely dependent on imported oil from external suppliers such as OPEC, Middle East, and West Africa. The region is greatly vulnerable to oil supply disruption due to greater dependency on imported oil supplies, and this dependency provided the initial impetus behind building strategic petroleum reserves.

In this context, a huge debate has been conducted on the peak oil time duration (Blanco et al. 2015). The situation

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of peak oil effects distress when global oil producers start to fail because the situation inescapably slid to disaster oil. According to (Sharma 1988), (Murphy et al. 1985) and (Brown 2018), bell-shaped profiles predicted the decline of US manufacture in the 1970s.The system of production and management of material wealth is a phenomenon that follows and is caused by some previous phenomenon, and this short spatial extent has a potential of defect and inertia restraints. The oil consumption by end-user is an instrumentality needed for undertaking for products and service and therefore the structure oil utility presents a true picture of something needed for planning for the current and future strategic petroleum reserves. As a result, the transportation routes of oil transportation are also severely affected by economic vulnerability. Misleading political actions and illogical strategic planning could lead to future oil disruption and worsening security measures in international mark. By this end, the Hubbert curves between these scopes we measured through the fuel demand and virtual growth rates of oil supply using the computable general equilibrium (CGE) model, which merged as feasibility complete report of the factors of oil markets.

However, due to insecure political issues and unstable economic conditions in the Middle East, oil imports face various uncertainties and risks (Sapkota et al. 2018). It is worth mentioning that there are many role players in the interruption of oil supply. For example, Saudi Arabia accounted for 17% of global oil exports in 2015, Iraq exported about 6.6%, the United Arab Emirates 6.5%, Angola 4.1%, Kuwait 4.3%, Nigeria 4.8%, and Venezuela accounts for 3.5% of total world oil exports (Lee et al. 2019). Unfortunately, these countries are considered the most vulnerable areas in terms of political risk and war (Lee and Choe 2019).

The aim of this research is to examine South Asian countries' option of building a strategic petroleum reserve. South Asian countries have customarily been rich in natural gas and oil; so far, this concern has received little concentration. However, their dependence on imported oil has increased rapidly in recent years (Wu et al. 2008). This dependence on oil imports, and the resulting defenselessness to oil price instability, is likely to grow in the future: oil consumption is expected to rise in the rapidly developing economies of South-east Asia, while oil production has been declining steadily since 1998 (Zhang et al. 2009) and (Mohsin et al. 2019c). To the best of the authors' knowledge, no studies have been conducted on South Asia's stockpiling and SPR policies, where the interactions between quota policies/import tariff and stockpiling policies have been analyzed. (Wu et al. 2012) proposed a dynamic programming model based on two-period model stages to measure the size of China's stockpile and the rate of optimum tariff (Mohsin et al. 2019b), (Mohsin et al. 2018a) and (Iqbal et al. 2019).

Although their findings were interesting, characterization of a two-period model would constitute an exception for dynamic growth with the time import tariff and the size of the SPR. The study lacks the strategies for optimal acquisition analysis, which makes it impossible for the study to develop strategies for optimal release and optimal SPR size with oil-supply disturbances or to investigate the development of important tariffs in time. Explicitly, their model is basically static with respect to the stockpile size and optimal tariff. In order to address this issue, we used a framework of multi-period dynamic mathematical to examine South Asia's policies of stockpiling, with consideration of the possible tariff polices. South Asia's SPR target is to maintain a sound level of SPR (100 days) by 2025 which would cause strengthen oil reserves in the region. The current study aims to answer these questions by employing a DP model and use it to investigate the strategies of optimal stockpile acquisition in view of oil price, costs, and risks. Our analysis also provides direction to decision-/policy-makers on the optimal management of the strategic petroleum reserve.

The rest of the paper is organized as follows: Section 2 provides the "Methodology"; Section 3 explains the "Results and discussion," and Section 4 provides the "Conclusion and Policy Implication."

Methodology

The stockpiling strategies depend on the future behavior of a number of stochastic variables, such as oil imports, oil prices, oil production, oil dependency, and GDP. Therefore, it is important to simulate the uncertainty in oil price model. The state of the world oil market and oil stock acquisitions or oil stock releases affects oil price. For instance, the acquisition of stockpile can generate additional oil demand in the global market, whereas the normal or disrupted market situation of oil can influence its physical supply, especially in oil-importing countries. This work models world oil consumption and world oil prices, net oil imports and domestic oil production, and GDP for both the South Asian region as a whole and each of its individual countries. Oil prices as real annual crude oil price, measured in 2011, (USD per barrel) are used. Even though the oil prices have fluctuated considerably in the short term, use of the annual average price is suitable in this study, since long-run stockpile climax and drawdown consistent policies are considered. The analysis of price model shows that the series of oil price in terms of P_K^0 can be modeled in the form of first differences before functioning and carrying out the regression analysis. The price U_K^0 model of oil price is presented as,

$$P_K^U = P_{K-1}^U + U_K^U + CK \quad (1)$$

Statistical behavior of real GDP, net oil imports, and domestic oil production require to be modeled because these key variables can be used to determine the oil dependency of South Asian countries.

End-user oil prices in oil-dependent economies are highly correlated with oil prices imported from OPEC. The increase in imported oil has strengthened expected transfers during the interruption of foreign oil supplies. During the export of crude oil products, entities should evaluate how changes in oil prices may affect end users. Historical experience proves the external cost of political action. For example, US military intervention in the Middle East has led to unsafe replenishment of oil resources (Kumar 2017). Military spending by local government-insensitive oil supply areas to strengthen security measures and develop strategic petroleum reserves (SPR) could be a response to a severely fragile economy. Governments need to balance spending to reduce the benefits of external factors and increase oil consumption (Mohsin et al. 2019a) and (Al Asbahi et al. 2019).

The USD volatility and risk factor is evaluated through the first logarithmic variance and the sum of the square of the first logarithmic difference is usually used to measure returns. It essentially reproduces the price change. Its index volatility can be calculated as follows (Wei et al. 2008) and (Murphy and Oliveira 2013):

$$D_m = \frac{1}{K_m - 1}\left[\sum_{T=1} K_m - 1\left(\log\left(\$v_{m,T+1} / \$v_{m,T}\right)\right)2\right]. \tag{2}$$

where Dm shows the amount of volatility in US dollar for a given year m and Km is the trading day in year m, while $\$v_{m,T}$ is US dollar index on the Tth day in year m.

$$HHI = \sum_{i=1}^{n}\left(w_{ij}\right)^2. \tag{3}$$

Petroleum geopolitical risk is the main component of petroleum geopolitical supply risk, which is the actual disruption in oil supply, strategic petroleum reserves, economic situation, political collapse, war, and insecurity of the petroleum-exporting country's government failure and political system. HHI (Herfindahl–Hirschman Index) is considered the conventional method of oil diversification index. The HHI index estimates and handles the concentration of oil supply (Li et al. 2017) and (Sun et al. 2019b), where i is the importing country (i.e., end user), j is the exporting country (ie source), Wij shows the share of supplier j in the total oil imports of country i, and n is the oil-importing country i total oil suppliers. Incorporating comprehensive country risk factors into the HHI index clearly indicates the risk of geopolitical oil supply, which is taken from the ICRG (International Country Risk Guide) and looks like a revised HHI index.

$$HHI{-}CRj = \sum_{i=1}^{n}\left(W_{ij}\right)^2 \times CR_j \tag{4}$$

Oil import dependence is often used to calculate a country's oil supply risk. It is worth mentioning that, due to diversified sources, CR shows the national risk as well-defined by ICRG, which translates a lower risk value of 100 and a high-risk value of 0. ICRG is an international commercial source of national risk in 140 economies around the world. Therefore, it is necessary to combine the diversification and oil import dependence index to measure oil supply risk. The structure of the OSRI (Oil Supply Risk Index) is as follows:

$$HHI \times Di = \sum_{i=1}^{N} Wij^2. \tag{5}$$

where D_i shows the dependency of oil importation which is measured as follows: D= $\frac{NI}{C}$, where C and NI show the crude oil usage of country i and total imports of crude oil respectively (Wu et al. 2009) and (Zhang et al. 2013). It is a market-clearing condition due to the continuous exponentially increasing demand on the oil market over time, while the oil supply on the market is of a static nature (Sun et al. 2019a) and (Iram et al. 2019). The oil price is represented as the starting point in the market. South Asian oil market insecurity's total cost having the SPR policy without an oil import tariff is presented as and usually it is equal to an import quota, given as:

$$\begin{aligned} TCSA(S,i,s,K) = & \int_{Pb_K}^{P(S(K),i,K)} D_{SA}(p,K)dp \\ & + P(s(K),i,K).s(K) \\ & + UHC.[S(t)+s(K)] + CK \end{aligned} \tag{6}$$

Normal state market oil prices without SPR attainment can be represented by Pb_t and it is the baseline oil price in time period t; D_{SA} is South Asia's demand of imported oil; UHC shows annual unit strategic petroleum reserves cost of holding, while S(t) shows strategic petroleum reserves size at the commencement for the time period t. Equation (12) shows South Asian oil market insecurity's total cost (indicated as TCSA) comprised of three parts: the loss of consumer's surplus in South Asia because of enflamed oil prices due to the enhanced demand-disrupted oil supply or oil stockpiling; sales revenue or purchase cost stockpile, in case of s(t) < 0; the cost of stockpile holding (Qaiser Alam et al. 2017) and (Bahel et al. 2013).

Further, the factors of oil markets remain dynamic with partial equilibrium evaluation of supply and demand amendments in the oil markets. These factors characterize the practical constraints comprising oil supplies due to the Middle East economies' effects on the decision of oil generation and the technical lethargy on the distribution of substitutes of oil and economic situations from the short-term consumers' adjustments. The oil producers from the Middle East strategically act on the oil market and they make their considerate investment decisions timely measuring the production capacity (Sun et al. 2020). In fact, if South Asia adopts strategic oil reserves and tariff/quota policies, it can be expected that South

Asia insecurity's cost of oil market would remain largely not the same from Eq. (14). More specifically, when South Asia's demanded trade-oil is computed with a quota M, South Asia's price of oil can be increased because of the level determined by the following formula:

$$Pv((OP_K),) = M + CK \tag{7}$$

M can be represented by $P_{SA}(M, t)$, while oil price at global market remained indistinct, which can be explained through the new global oil-market, where $DR\ ((OP_t), t)$ is the demanded oil trade from all over the world. For example, it shows the oil price of the world for South Asia's policy of quota as $P^m(M, t, i, s)$. The consumer surplus loss of South Asia is assumed through a mixture of quota and strategic petroleum reserves policies. Consequently, adding sale revenue or stockpile purchase cost, holding cost and consumer surplus loss simultaneously, South Asia's cost of oil market insecurity existence of both quota and strategic petroleum reserves polices. These policies can be illustrated by the quota policy optimization of South Asia needed the cost minimization of oil insecurity in keeping the strategic petroleum policy of reserves. It can be taken the derived cost of oil insecurity $TCSA^M(M, S, i, s, t)$ with respect to the import quota M equivalent to zero in order to get the condition of first order for the amount of optimal quota.

$$P_{SA}(M*, i, , K) = (S + M*)*\frac{\partial P^M(M*, K, i, s)}{\partial M*} \tag{8}$$

Equation (8) describes M* amount of optimal quota, which is considered as the function of the present market situation i, stockpile releases/acquisition s, and time periods t, i.e."

$$M* = \varphi(i, s, t) \tag{9}$$

Additionally, a significant first alternative to oil production of liquefied petroleum contains first and second cohorts of biofuels starting from renewable energy resources. Their dissemination is administrated by oil supply curves. At each stage, the market share of biofuels is an increasing function of oil prices and it captures, in a simple way, the competition between oil-based liquid fuels and biofuels. The value of coal-to-liquid (SO) shows major substitute of oil. We presented here that this is the infinite backstop equipment succumbed to distribution volume restrictions. This research shows that the generation of infinite substitute initiate least-cost deposits of oil reserve. However, SO provides a limited production due to restrictions on delivery capacity because of decision of previous investment, and profitability forecasts for SO are undervalued due to poor foresight. These profit projections satisfy oil prices' aggregated function from the oil prices in the past which can be written as: $p_{cum}(t) = \sum_{i=2015}^{t} p_{oil}(i)$. Once the price of oil surpasses pso, SO oil production at time t is assumed to be,

$$SO(t) = s(p_{cum}(t)).[D(t){-}S(t)]. \tag{10}$$

Liquid fuel final demand comes from domestic industry and household energy demand resulting after profit maximization and utility, respectively. Despite stagnation in the recycling of end-use machinery, the speed of functional processes is a major decoupling between economic growth and development/demand of liquid fuel. It can only be achieved after the regeneration of multiple investment vintages.

Results and discussion

The global production profile of oil demonstrates a bell-shaped curve through sufficient disruption in oil production trends at the peak oil time duration, and rapidly decline thereafter. On the contrary, in the low deployment scenario, short-run prices' substitute of oil demand leads to a lower profile while the reverse situation of oil generation during the peak oil period which is smooth whereas the volume of oil production reduction caused at a reasonable step. Total oil supply level moves towards a higher level than in the market flooding situation after 2040 (Table 1).

Over the period 2010–2050, the average GDP growth rate is projected designate 1.61% in the low distribution state against 1.49% during the situation of market flooding, (Fig. 1).

Results shows that active growth is above the expected evolution over the whole "pre-peak oil period" in a market overflowing situation and rationally allows for advanced development charges due to low-cost introductions of oil and reduced dynamism for the family unit and inventiveness. Throughout the "peak oil" phase, the reduction in financial development starts preferably in the market flooding situation and is more penetrating since peak oil causes more damage to the oil-dependent budgets. During that period, the actual rate of development falls below the ordinary rate the 10 years (2030–2040) and therefore remains to be observed between 2037 and 2047. This is similar to high-risk stages of social strains. Table 2 shows the GDP-oil price elasticity assumptions for the individual South Asian countries: these estimates are again based on our analysis of each country's net oil imports and GDP, and are broadly consistent with empirical estimates of the macroeconomic effect of oil price shocks in South Asian countries. Countries listed in Table 3 are net oil importers whose economies are negatively affected by oil price shocks, and it is these 8 countries that could potentially build their own individual petroleum reserves. A surprising inclusion, which continues to export crude oil but has recently

Table 1 Average growth rates in percent

		(2010–2050)	(2010–2025)	(2025–2040)	(2040–2050)
Growth rates (Constant nature)		1.51	1.68	1.31	1.21
Actual rates (Varying nature)	Short term	1.61	1.89	1.44	1.23
	Long term	1.49	2.11	1.30	1.17

become a net oil importer due to its growing volumes of imported refined products.

More stringent rules also increase the total expected cost of stockpiling, both because of the higher cost of building up a larger stockpile and the reduced benefits to GDP (since the constraint on the final period stockpile limits the planner's ability to respond to oil price shocks). There is thus a trade-off between the size of the final stockpile and the expected costs of the stockpiling policy. Sometimes the rule may indeed be too stringent, i.e., it may make a stockpiling behavior appear to be in the final stages of the planning horizon. In such a case, the rule is considered overly stringent as the stockpiling behavior is not derived by the optimization conditions of the planner, but driven entirely by the constraint, culminating in a final level of reserves larger than was ever required during the planning horizon. The stringent rules, the expected cost is negative, which implies that the benefit of building the petroleum reserve to GDP (which refers to the GDP losses avoided due to the reduced volatility in oil prices brought about by stockpiling) is larger than the cost of holding the reserve. However, with sufficiently stringent rules, the expected cost becomes positive. This implies that the social costs of building the reserves exceed the GDP benefits *within* the current planning horizon. There is thus a trade-off between the welfare of the current generation (represented by the expected cost) and that of future generations. Our findings are consistent with the outcomes drawn by (Gao et al. 2018) and (Liao et al. 2016).

Obviously, neither overly stringent rules that impose a large cost on the current generation, nor rules that bequeath very limited reserves for future generations, seem optimal from a social perspective while the. results show that the extra abundance of funds replaces earlier development with a larger reserve contribution to these oil-importing financial prudence. Similarly, it controls all parametric expectations that the Little Positioning situations are more favorable to financial prudence as they minimize their defenselessness to peak oil. On a regular basis, this advantage is small and slightly oblivious to parametric expectations, with less than 0.1% change in extra risky cases (graphical explanation used by (Waisman et al. 2012).

Additionally, like in the intermediate circumstance, a considerable extra associated double is found when in view of the time outlines. We examine these possessions by defining the areas of reduction charges and finished possessions, where each estimation situation is leading for Middle East producers

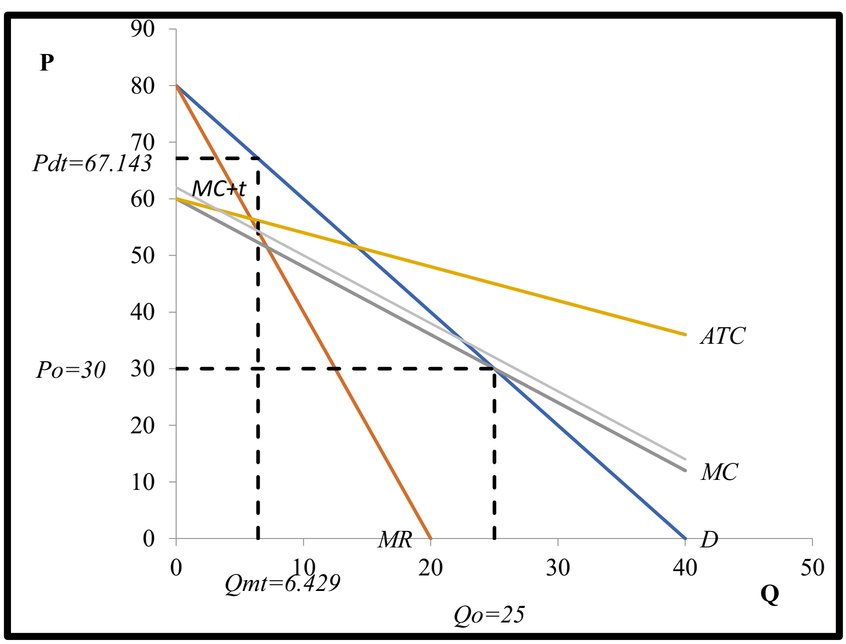


Fig. 1 Price and supply behavior during Middle East monopoly

Table 2 South Asian countries oil dependency

Country	Imported oil dependent?
Afghanistan	Yes
Bangladesh	Yes
Bhutan	Yes
India	Yes
Maldives	Yes
Nepal	Yes
Pakistan	Yes
Sri Lanka	Yes

under the binary choice measures labeled in (graphical explanation used by (Waisman et al. 2012)).

Because of the unstable crude oil consumption between oil consumers and producers, the trade of oil in the world has grown quickly during the past two decades. Since 1990 to 2010, imports of oil in the world increased by 75%. The inequity in the distribution of oil supply caused by the differences between oil consumers and oil in the world. Vulnerability in oil supply considers the unanticipated disruption of oil supply which does not instantaneously resolve through the world oil marketplace. It asses the risk of oil availability and disruption in physical supply of availability. This study (Wang and Zhang 2019) anticipated crude oil supply risk factor for measuring the risk of physical damage. Oil supply vulnerability indicators have been designed and recommended to measure long and short-term crude oil supply risks. Supply vulnerability factor and its sub-indicators are used to assess the disruption of oil supply in specific countries and specific energy markets. Indicators such as liquidity and geopolitics are used to assess supply risk. This is due to exporting countries oil consumption cannot be used for the purpose of oil import.

The benefit of the proposed method is the certain and clear number, while the cost of various strategies which can be compared with different market oil scenario. Several measurements of oil imports to the South Asian economies range from $ 600 billion to $ 15 trillion (Zhang et al. 2016), but this number remains a useful benchmark. In comparison, in the first 5 months of 2011, China's oil import cost was $ 79 billion, accounting for 12% of imported goods cost. Per capita GDP factor plays an important role in the overall oil vulnerability index. The USA has the highest GDP per capita at US $ 56,115, while Afghanistan has the highest GDP per capita at US $ 594.3. European countries have higher GDP per capita. On average, the per capita GDP of European countries is more than $ 30,000, which can be interpreted as a less fragile situation. Based on GDP per capita, less vulnerable, and least vulnerable. As shown in Fig. 2, the proportion of imported oil over GDP is measured by imported GDP. The highest value in Afghanistan is 0.27621, while the lowest value in the USA is 0.007351.

Table 3 Total expected cost (in US$ million) of managing the strategic petroleum reserve

Final stage rule (days)	0.95	0.98
0	89	44
30	89	44
60	89	44
90	89	44
120	89	44

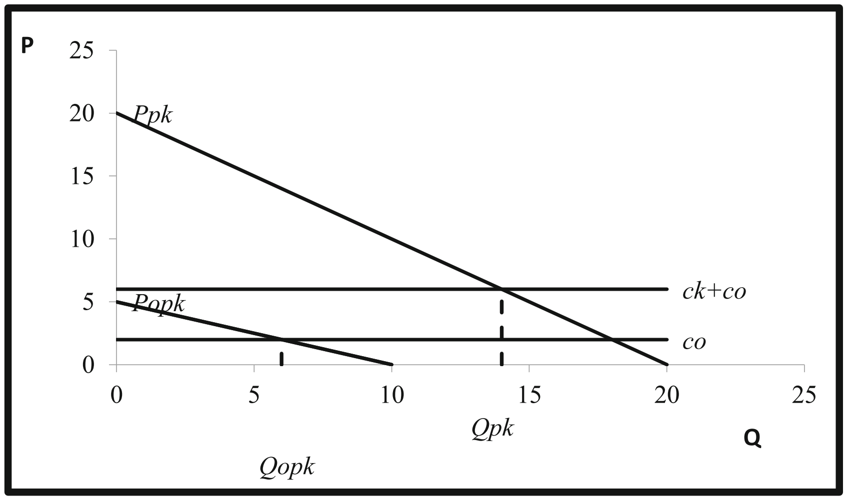
If the supply of imported oil suddenly breaks due to political, economic, military, or any other unpredictable reasons, huge economic costs and welfare losses will increase. At present, a substantial complication of preventing government spending, and welfare loss due to physical interruption of oil supply, is to improve the interruption of oil supply in countries and regions.

The short-range properties are designed during two self-regulating development, which on one hand, do not justify long-term supply reduction due to their short-term focus (Behmiri and Manso 2013). However, econometric analyses were carried out after the oil tremors explore the show networks between oil prices and GDP, (Lee et al. 2017). These studies show that demonstrating movements can better repeat the experimental amount of the financial effect of oil price variations if they include the following: (1) mark-up valuing to seizure marketplace limitations; (2) due to additional parameters between capital and energy, (Okullo and Reynès 2011) the capital intake rate is imperfect when the full intake of the connected generation capacity cannot be achieved; (3) a description of skills to stand for the disinterests capital stock (Behmiri and Pires Manso 2014); (4) resistances among the reorganization of resources obliquely varied segments producing distinguished ranks of lazy manufacturing capacity (Behmiri and Manso 2013) resistances in the rearrangement of employment through heterogeneous areas affecting differentiated levels of joblessness, (graphical explanation used by (Waisman et al. 2012)).

Certainly, in case of low oil resource, the peak oil time duration is nearly pricing trajectories of oil, nonetheless, the effect at long-run oil prices as they regulate the oil supply disruption at the path of demand and supply trends (Fig. 3). Similarly, the inter-generations rule prescribes reinvesting the benefits from oil stockpiling (in the form of benefits to GDP and revenue from stock sale) in further stock purchases, keeping the net benefits from stockpiling equal to zero.

Table 4 shows that the maximum top oil producer and consumer reached during the planning having the larger values of in MMB (0.90, 0.95 and 0.99) discount factor, while it ensure more weight to the future impact of oil disruptions on GDP and less relative weight to the current cost of building up the reserve, therefore the stockpile size increases. In the analysis so far, we have effectively treated the South Asian countries as a single decision-making unit and deliberately

Fig. 2 Peak load pricing



abstracted away from problems of co-ordination and cooperation. In practice, a mechanism for sharing these costs has to be implemented in conjunction with the development of any regional strategic petroleum reserve. One possible approach involves sharing costs in accordance with each country's share of South Asian net petroleum imports. While this approach is intuitive and relatively simple to implement, it does suffer from some drawbacks.

The loss of government work is an important stimulus for measuring welfare gains or losses related to the uncertainty of imported oil for various reasons. Only after the potential dependence of imported oil can the cost be quantitatively measured by policy-makers and the government be able to make adequate energy policy decisions to increase public interest. However, oil imports face a variety of uncertainties and risks as the major fossil fuel and unbalanced economic situations (Mohsin et al. 2019a). Various factors role play in the interruption of oil supply. For example, Saudi Arabia responsible for 18% of world oil exports in 2015, Iraq contributed 6.6%, the United Arab Emirates contributed 6.5%, Angola contributed 4.1%, and Kuwait contributed 4.3. %, while Nigeria Venezuela contributed by3.5% (4.8%) of total world oil exports. Market liquidity is also an influence parameter of the overall oil vulnerability index. Of all these countries, the highest values for China, the USA, India, South Korea, and Japan are equal to 0.167, 0.165, 0.09, and 0.69, respectively, suggesting that these countries are the worst. Bhutan, Nepal, Afghanistan, and Bangladesh actually have the same value of 0.001, which is a better indicator of market liquidity. Countries with less market liquidity, especially Afghanistan, Pakistan, Nepal, Bhutan, and Bangladesh, have greater ability to switch between different oil suppliers.

Though in general, countries with greater net petroleum imports benefit to a greater degree from stockpiling (and thus may be expected to incur a greater share of the costs), (Fig. 4) the relationship is not perfect. For instance, Singapore's net petroleum import numbers tend to over-state the economy's dependence on imported oil, since they include oil products (fuel oil, gas oil and jet fuel) supplied to international aviation and marine bunkers. An alternative approach is to share costs in proportion to the total expected GDP benefit each country derives from the regional strategic petroleum reserve. This

Fig. 3 Marginal cost and inverse demand function

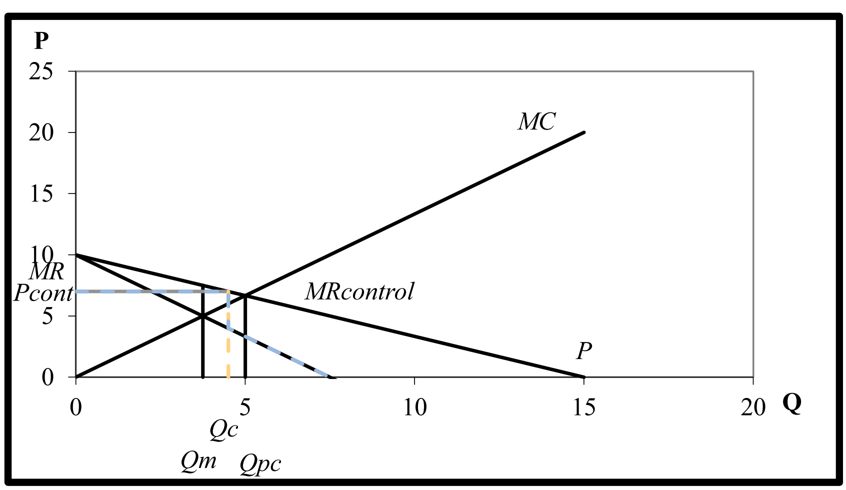


Table 4 Crude oil producers and consumers

Top 10 oil producer	Percentage	Top 10 oil importers	Percentage
Saudi Arabia	17	China	17.3
Russia	11	USA	16.1
Iraq	6.6	India	9.1
UAE	6.5	Japan	7.6
Canada	6.4	South Korea	6.6
Nigeria	4.8	Netherland	4.4
Kuwait	4.3	Germany	4.3
Angola	4.1	Italy	2.8
Venezuela	3.5	Spain	2.8
Kazakhstan	3.3	France	2.7

Source: BP Statistics &World exports

would yielded due to the difficulty of determining, in practice, the economic benefit to each country from the SPR.

The oil producers economic trade-off

The Middle East time profile of profits from oil production were generated through price and volume. Short-run revenues of oil production are greater under the scenario of market inclined towards an increase in revenues generated by oil. However, this increase is amplified in the scenario of market flooding due to greater long-run oil prices.

In the scenario of market flooding the South Asian opportunities depends on the importing situation of oil (Fig. 4). The pricing decisions which make the best use of their households' surplus and to compare the effects of general equilibrium of the two pricing strategies. Results show that the populace's surplus *I* shows the compensative effective and real difference in revenue, correspondingly, whereas the later assessment measures the sum of income which caused no change in the utility, concerning the given changes in comparative prices. Herewith standard, the scenario of market flooding becomes a practical alternate option since the social discount rate is less than the private discount rate.

Table 5 shows the households' surplus with different scenarios (Billion $). The variance between the two results produced by the impacts of the two investment plans on the transition dynamics of the short-run economy, most of which depend on revenues from oil generation. For the balance of payments assumption, the higher the short-term oil export revenues under the low deployment scenario, which are dependent on local currencies, the higher the exchange rate and the greater imports of industrial products. It penalizes domestic producers and decelerates the transition of the Middle East economies beyond oil-based revenues to industrial development. In contrast to the market flooding scenario, lower oil revenues have resulted, which allows for lower exchange rates. The improvement of domestic production in industry partly counterbalances short-run victims in revenues of oil and well prepares the Middle East economies for the post-oil period. Short-run oil revenues inflows originated at a pace well-matched to the domestic economy's preoccupation capacity, while inflows form peak oil benefits to the developed industrial organization.

The tradeoff and SPR rule may indeed be too stringent, i.e., it may impose a stockpiling behavior at the final stages of the planning horizon. In such a case the rule is considered as overly stringent, as the stockpiling behavior is not derived by the optimization conditions of the planner, but driven entirely by the constraint, culminating in a final level of reserves larger than was ever required during the planning horizon. After cost and diversification, the geopolitical factor is the third highest contributor in the region's overall vulnerability contribution score. In general, domestic oil reserves and domestic oil production show a degree of dependence on imported oil and

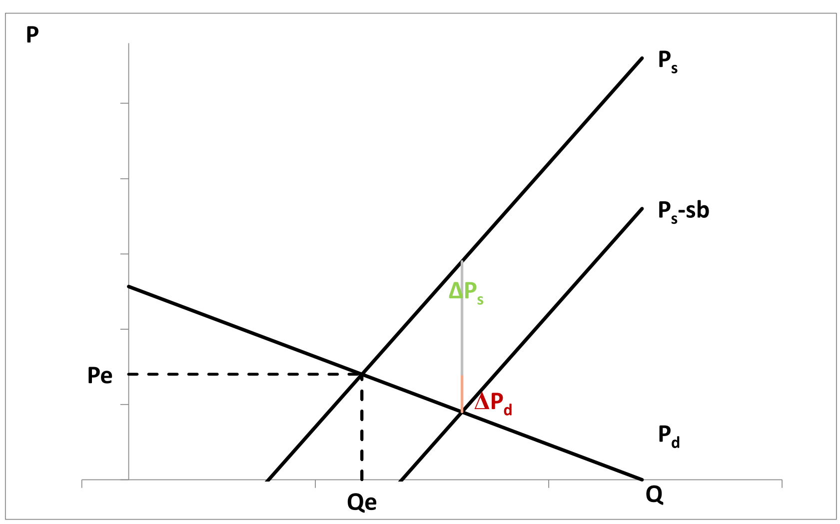


Fig. 4 Demand and supply elasticity varying with tax and subsidy

Table 5 Households' surplus with different scenario (Billion $)

Discount rate (%)	Discounted surplus
4	+ 1973
8	+ 249
11	+ 29
12	+ 4
14	+ 29
20	+ 61

geopolitical oil risks. It shows that countries with the highest geopolitical oil supply risk are less diversified among oil suppliers.

Conclusion and policy implication

This study measures the notion of peak oil time periods in the modeling framework of a general equilibrium that characterizes restrictions on the fuel demand, oil substitutes and the short-term adaptability of oil supply. In this proposed framework, inadequate foresight and inertia give rise to a sudden increase in oil prices when oil-importing countries (South Asian countries) are extremely dependent on oil once they have entered the oil depletion period. By taking into account the two situation of oil varies only slightly, which can cause different oil price time profiles, rent development and growth patterns of the economy. From the perspective of oil exporters, lower prices of oil destabilize temporary revenue export but inspire to use of oil in oil-dependent countries. The oil-importing countries become extremely dependent on oil from the oil exports. As a result, it would be beneficial for oil producers to receive a temporary sacrifice in their short-term export revenues because they would benefit from higher long-term revenues in the peak oil post-date period. Given the past behavior of oil prices, oil production and oil imports, and population and GDP growth in the South Asian countries, we have generated a wide range of future scenarios for these prices and imports.

We then analyze these scenarios and employed a stochastic program to optimize the size and buildup of the strategic reserve over the next 25 years. The model that we have used is capable of selecting the optimal buildup and drawdown strategies for the reserve while simultaneously taking into account intergenerational equity considerations, a feature that distinguishes it from previous analyses of strategic oil stockpiling. Model simulations suggest that it makes sense for South Asian countries to build up regional oil reserves, with the potential for significantly increase social welfare. First, we demonstrate that with a finite planning horizon, the selected stockpiling strategies will be suboptimal without a constraint specifying the minimum reserves to be held in the final period. Then, in the final period, we compare different decision rules for the target reserves and argue that an inadequate criterion is provided by the intergenerational rule, which balances between the dual objectives of mitigating the GDP losses from oil price shocks and saving an adequate level of oil stocks for future use. Comparison of the regional petroleum reserve varies with an alternative stockpiling regime, where each South Asian country builds its own petroleum reserves without taking into account the stockpiling activities of its neighbors. We find that in the absence of cooperation, each country builds up large petroleum reserves individually, leading to an overall level of reserves in the region. A regional policy framework should be established to maintain the emergency threshold of strategic oil reserves in the region. Cross-border trade in regional oil production should ensure in the region of oil importing countries.

Limitations of the study contain the lack of certain indicators such as strategic government decisions, number of loading material (days) data, and especially the survival days withholding the strategic bulk for crises. The study can be extended for the comparison of developed and developing economies. Also, the methods used can be extended by adding certain variables such as crude oil price shock and effects of stock prices associated with oil prices at national and international levels.

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