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Crude oil production in the Persian Gulf amidst geopolitical risk, cost of damage and resources rents: Is there asymmetric inference?

Ifedolapo Olabisi Olanipekun [a], Andrew Adewale Alola [b,c,*]

[a] Department of Economics, Adeyemi College of Education, Ondo, Nigeria
[b] Department of Economics and Finance, Istanbul Gelisim University, Istanbul, Turkey
[c] Department of Financial Technologies, South Ural State University, Chelyabinsk, Russia

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ABSTRACT

The strategic importance of the Strait of Hormuz to the global oil market has been linked with incessant tensions among the oil player states in recent times. As a main contribution to literature, the current study examines crude oil production in the Persian Gulf amidst geopolitical risks. In achieving this objective, the non-linear autoregressive distributed lag (NARDL) approach is employed to examine the impact of geopolitical risk, cost of oil damage, total resources rents and crude oil price on the production of crude oil in the Persian Gulf over the period 1975–2018. The study found that positive shocks in geopolitical risk and cost of damage have statistically significant and dynamic negative impacts on oil production in the short-run. However, negative shock in the dynamic value of crude oil price in the long run and short-run exerts a statistically significant and negative impact on the crude oil production. Additionally, whether there is a positive or a negative shock in the resources rents, it causes a significant positive impact on oil production in the long run. Therefore, the current study offers policy indication that eliminating or reducing regional tension in the Persian Gulf has the potential of minimizing oil flow hindrances in the Strait of Hormuz and other crude oil exploration platforms and transportation channels across the globe.

1. Introduction

The increasing cases of state/regional instability, terror attacks and other adverse geopolitical events across the world have kept geopolitical risk on the rise. The resulting geopolitical tensions have not only caused direct destruction of human lives, it also influences the preference of economic relationships. As an important global commodity, crude oil cannot be isolated from this international dynamism. Thus, oil exporting countries also respond to evolving geopolitical tensions by taking into account the possible reflexive strategies from other countries. The world's giant economies – United States, European Union (EU) and the giants in Asia, Japan, China and India – where demand for oil is increasing in response to output growth, are highly dependent on the Persian Gulf oil, Russian oil and Caspian region oil (BP, 2004). The Persian Gulf is believed to be the custodian of 60 percent of Organization of Petroleum Exporting Countries (OPEC) oil reserves (OPEC, 2018). Considering, therefore, the strategic position of the Persian Gulf, it cannot be assumed that oil production process in this region will be smooth during geopolitical crises and immediately after. It is also difficult to assume that the current and future geopolitical crises will not exert much degree of uncertainties as previous crises. This is because market forces and some natural events sometimes dictate actions of economic agents, governments, investors, producers, marketers and consumers. Yet, the literature on the importance of geopolitical risk in oil production is yet to be conclusive.

Indicatively, the stability in the oil market is dependent on the capacity of producers to meet the increasing demand. In addition, oil market easily respond to demand dynamics arising from price volatility and other external factors attributed to oil stakeholders (Baumeister and Kilian, 2016; Correlje and Van der Linde, 2006; Hamilton, 2009). Furthermore, the decision to embark on production and the oil production process that begins from the point of exploration to the point of making it available in the market depend on the ability of producers to invest and their ability to make it available at the market at the right time (Correlje and Van der Linde, 2006; Stevens, 2005). These are fundamentally determined by political, economic and environmental factors.

Apart from economic and policy uncertainty, geopolitical risk is

* Corresponding author. Department of Economics and Finance, Istanbul Gelisim University, Istanbul, Turkey.
E-mail addresses: dido_038@hotmail.com, olanipekunio@aceondo.edu.ng (I.O. Olanipekun), aadewale@gelisim.edu.tr (A.A. Alola).

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another form of uncertainty that could have adverse effects on economic activities (Caldara and Iacoviello, 2017). This implies that geopolitical risks also have some influence on the economic factors that determine oil production such as oil price, oil demand and supply, exchange rate, mobility of resources, extraction costs and investment in alternatives. For instance, imperfect mobility of resources leads to technical and operational disruptions thereby causing capacity limitations. Furthermore, spot oil prices are driven by the mismatch between global oil supply and demand, a huge imbalance could occur if supply channels are disrupted or if demand falls due to economic shutdowns arising from unrest. Oil prices are highly elastic to these changes, if oil price falls for instance, it forces oil companies to cut down on expenditure while they review their investment decisions and plans.

Geopolitical risk weakens the climate for investment as it creates economic instabilities, exchange rate uncertainty and generally, Economic Policy Uncertainty, 2019. Geopolitical risk is among the major determinants of investment decisions, it dictates the direction of investment, production activities and government spending as adverse geopolitical event diverts investment spending into more of government spending towards security and reconstruction (Balcilar et al., 2018; Blomberg et al., 2004; Caldara and Iacoviello, 2016). Uncertainty arising from geopolitical instability causes investors to embrace the wait-and-see concept by holding-on investment decisions while they engage precautionary saving because the value of the future is made lower than the present under uncertainty (Bloom, 2009; Eckstein and Tsiddon, 2004). Oil production, therefore, becomes sensitive to geopolitical uncertainty arising from adverse effect on timely and adequate investment in production (Barkoulas et al., 2008; Correlje and Van der Linde, 2006).

Geopolitical competition and rivalry also limit investment choices of the oil and gas producing countries because of their preferences in the choice of foreign direct investment (FDI) which are allowed to facilitate oil and gas production in these countries (See Wolfe and Tessman, 2012). The countries' national oil companies may be ill equipped to meet the investment demand of expected change in production. Nevertheless, FDIs are allowed to operate under certain environmental conditions, otherwise, there would be constant disruption in production activities as citizens protest against environmental degradation. In order to avoid potential conflicts, government must reduce greenhouse effects of burning fossil fuel, oil spillage caused by accidents that occur onshore and offshore during oil drilling and oil transporting by sea or pipelines and soil damage caused by mining. This would imply stringent measures such as imposition of carbon tax to see that oil companies do not exceed the greenhouse gas emission quota (carbon cap) in production. This makes the choice of investment in alternative energy more attractive. The different ambitions of these stakeholders, therefore, give birth to the roles they play in the determination of sufficient investment in oil production.

Many of the Persian Gulf producers are barely developing economies, which makes them more vulnerable to external geopolitical pressures. They are oil dependent, economically fragile and depend on foreign capital inflows. Thus, they remain vulnerable to both external and internal instability (Correlje and Van der Linde, 2006). They are also politically vulnerable. Some are already characterized by internal crises and are politically unstable due to corruption and economic leakages, while oil price shocks, oil revenue, internal conflicts over economic rents and controversies over resource control sparks up political unrest. For instance, the instability in Iraq still has a major impact on Persian Gulf oil production, it prevents investment by international companies. With such regular disruptions and slow capacity replacement, there will be capacity shortage and limited productivity. Considering the delicate situations on the importance of the Persian Gulf oil, the role of geopolitical risk in the oil production needs to be addressed with special focus on the Persian Gulf countries. This has now been made possible by the recent development geopolitical risk index by Caldara and Iacoviello (2016).

In line with the aforementioned motivations, this study is aimed at examining the impact of geopolitical risk, cost of damage, the total natural resources rents and the crude oil price on the crude oil production in the Persian Gulf region covering the period of 1975–2018. The investigation is important because it contributes to the literature in several perspectives especially on the ripple effects of geopolitical risk.

First, it contributes to the growing literature on risk and uncertainty by showing how geopolitical risk affects the oil production especially for the case of the Persian Gulf region which has sparsely been covered in extant literature. Secondly, in addition to the geopolitical risk, the current study has incorporated other novel factors such as the total natural resources rents and the cost of damage as additional explanatory variables. Oil rent has often been found to be an essential component of oil rich economies (Aimer, 2018; Fuinhas et al., 2015; Matallah and Matallah, 2016). To the best of authors' knowledge, resources rent has not been examined in the context of the drivers of crude oil production. Our study also deviates from Cunado et al. (2019) who included both world oil production and geopolitical risk as determinants oil price. We have rather specified oil price with geopolitical risk as co-determinants of production. Lastly, another novel contribution of the current study is that a non-linearity econometric approach is being employed. Specifically, the non-linear autoregressive distributed lag (NARDL) technique is being employed to adequately account for the potential shock effects on the aforementioned factors.

Therefore, the study outline is presented in the following order: the next section (2) briefly describes geopolitical risk and Persian Gulf scenario followed by outlined related studies in the context of crude oil production in Section 3. The examined data are described and followed by the application of the methodological approaches in section 4. In section 5, the estimated results were discussed while the concluding remark on the study is outlined in section 6.

2. Geopolitical risk and Persian Gulf scenario

Capacity expansion has in the past been marred by geopolitical crisis that rocked the Persian Gulf, an example is the production loss of about 5 million barrels per day recorded three decades ago (Verleger, 1990). There was an oil crisis three decades ago during the Persian Gulf War of 1990–91 when Iraq invaded Kuwait following an accusation that Kuwait was slant-drilling Iraqi's petroleum. While recognizing the possibility that the Iraqi forces could, by this, encroach Saudi Arabian oil fields through the Eastern part of the country, it became necessary that the United States, through its military forces, defended the Kingdom, especially because of the interest of United States in their oil resource. The United States military presence was not limited to Saudi Arabia but were also positioned in United Arab Emirates (UAE), Quarter and Turkey (Eilts, 1991). Coupled with the intervention of the United States were other Arab contingents led by Egypt, together with other Western nations in response to the call from Saudi Arabia and Egypt to intervene. By the time the crisis subsided, both Iraq and Kuwait had suffered massive damage, there were economic damages, real sector and financial losses as expatriates in this region, especially in Kuwait, had to flee leaving their investments behind.[1]

As an immediate consequence of the conflict, world oil production fell by about 4.5–5 million barrels per day as both countries suffered quantitative loss in their oil production. Even though Saudi Arabia and Qatar increased their production, they were unable to compensate for the loss from Iraq and Kuwait. In July 1990, Iraqi's oil production stood at 3.10 million barrels per day while that of Kuwait was at 1.60 million barrels per day. These daily productions are against the maximum capacity of 3.4 million barrels per day for Iraq and the daily projection of

[1] For more on this see: https://history.state.gov/departmenthistory/short-history/firstgulf, https://www.history.com/topics/middle-east/persian-gulf-war, https://www.britannica.com/event/Persian-Gulf-War.

2.0 million barrels per day for Kuwait, if there had been no security threats (Archer et al., 1990; International Energy Agency, 1991; Mabro, 1994). During this crisis, Iraqi oil were banned from passing through oil pipelines in other territories (Eilts, 1991). There were other economic sanctions against Iraq apart from embargoes on shipping petroleum out of Iraq and Kuwait. This led to very high cost of producing oil, supply shortage, and consequently high oil prices.

Again, geopolitical risk became an important issue after the September 11, 2001 attacks on United States. This severed United States' relationship with Saudi Arabia that led to the United States withdrawing its troops from Saudi Arabia in 2003, and some resultant antipathy towards the United States in assertive foreign policy on oil market stability conditions (Correlje and Van der Linde, 2006). In 2018, there were also sanctions against Iran by the United States that led to a sharp contraction in the Iranian economy such that the Iranian Rial lost value and their inflation rate rose sharply. Among the consequences of these was the sharp drop in the Iranian oil production as foreign investors were driven away due to unfavourable economic conditions. Another crisis has rocked the region between 2019 and early 2020, which is a crisis of confrontation between Iran and the United States following a suspected threat on Strait of Hormuz oil shipping. Tensions were further built around the Strait of Hormuz in June 2019 when Iran shot down a surveillance drone belonging to the United States. Two oil tankers belonging to Saudi Arabian National Petroleum and Natural Gas Company were damaged in a sabotage attack and more damages were reported in multiple attacks on Saudi Arabian oil pipelines.

Attack on energy facilities seems to have been a powerful weapon against the large economies who are directly and indirectly dependent on Persian Gulf oil. Oil transportation from the Persian Gulf are often at the risk of downstream bottlenecks and terrorist attacks especially through the Strait of Hormuz where about 88 percent of oil from this area pass through. There is needless high cost in transportation, disruption in the distribution channels and anxiety over closure of carnal, such as disruptions often experienced at the Suez Canal in the process of transporting oil (Morse and Richard, 2002). This stretches the cost incurred in production, which has considerable influence on production decisions, and consequently, disruptions in production process. (See also Rodrigue, 2004).

3. Related studies: a synopsis

In the extant literature, so far there seems to be lack of empirical study that present the link between oil production and geopolitical events, except for a few related studies. Cunado et al. (2019) included world oil production in their time-varying parameter structural vector autoregressive (TVP-SVAR) model to assess oil price response during geopolitical risk. The results suggest that oil price increases during geopolitical risk but not with a persistent rise, and that the volatility of shocks to growth in world oil production varies and declines over time. Furthermore, the decline in world oil demand during high geopolitical risks implies a decline in oil returns. Barkoulas et al. (2008) showed the link between oil prices and risk reactions of commodity linked-equity during a geopolitical event and confirmed that risk levels in oil industries increased following the September 11, 2001 event. There are indications that geopolitical risk might weaken returns on oil investment by apparent uncertainty.

Uddin et al. (2018) studied the causal relationship between oil markets and geopolitical, economic and financial uncertainty through an entropic wavelet analysis and also observed a nonlinear relationship between oil markets and the types of uncertainty. The association of oil production with geopolitical uncertainty is hinged on the fact that political uncertainties are correlated with business cycle (Azzimonti and Talbert, 2014; Azzimonti, 2018). Bloom (2009) showed that uncertainty shocks affect investment by creating a 'wait-and-see' effect while Baker et al. (2016) showed that uncertainty leads to investment decline, and thus, lead to output decline. Therefore, decline in real economic activity is a consequence of high geopolitical risk as opined by Caldara and Iacoviello (2018). An empirical evidence of this is shown in Cheng and Chiu (2018), that economic contractions are associated with shocks to global geopolitical risk while geopolitical risk explains between 13 and 22 percent variation in the share of output.

The theory of irreversible investment suggests that there is an asymmetric cost of adjustment in capital formation. According to this theory, adjustment costs are nonlinear due to the different values placed on an option to delay when compared to the choice to make an investment immediately (Bernanke, 1983; Dixit et al., 1994; Mohn and Osmundsen, 2011). Mohn and Osmundsen (2011) used data from oil and gas industry to validate this hypothesis for oil exploration activities, showing that there can be assymetry in oil investment. Therefore, Bernanke, 1983 bad news principle is applicable to oil investment and exploration in oil industry. This principle submits that unfavourable news in the industry will increase the value for an option to invest in future and limit exploration undertakings in the present, while favourable news has no relevance for the option to delay investment. On this premise, investors will avoid commitment during high geopolitical risk until they can ascertain the long run returns on such investment. Moreover, alteration of economic policies and shocks in public expenditure are among the consequences of major geopolitical event, these are associated with uncertainty capable of influencing the economic and business cycles (See Bloom et al., 2007; Mendoza and Vera, 2010; Tazhibayeva et al., 2008).

In addition, extant studies have presented the direct and indirect link between the cost of environmental damage and industrial productivity vis-à-vis oil productivity. For instance, upon conducting investigation with 267 firms in the United States, Sharfman and Fernando (2008) illustrated that a minimized environmental cost vis-à-vis a better environmental risk management is akin to lower cost of capital. Sharfman and Fernando (2008) further observed that improved management of environmental risk expectedly yield minimal equity capital and ensure a shift from equity to debt financing. Similarly, the study of Mirasgedis et al. (2008) hints that environmental cost from industrial activities is capable of affecting the technological and policy directives. This is in line with the natural intuition that the desire to mitigate carbon and pollutant emissions through energy and environmental policy adjustment could indirectly mean minimizing conventional or fossil oil output (Krewitt et al., 1999; Zhang et al., 2007; Alola and Alola, 2018; Adedoyin et al., 2020a,b). In clear terms, Abdul-Manan et al. (2017) employed the linear programming model to examine the effect of carbon pricing on the refinery productivity in six regions (the North America, Latin America, Europe (including the CIS), Middle East, Asia (excluding China) and China.). Thus, Abdul-Manan et al. (2017) opined that effective carbon pricing policy is suitable to minimize emissions leakage from the refineries especially when there is priority of sector utilization of energy consumption. However, in extant literature, unrelenting studies have continued to illustrate the environmental impact of carbon emissions across the globe (Ozturk and Acaravci, 2010; Bekun et al., 2019; Adedoyin et al., 2020a,b; Adedoyin and Zakari, 2020; Asongu et al., 2020; Kirikkaleli et al., 2020).

This research therefore focus on the non-linear relationship between oil production and geopolitical risk in addition to other determinants of oil production. This is to account for the possibility of a sectoral shifts (resulting from shock) in resources and sectoral reallocation of resources during or after certain event. The gap in the literature that the study intends to fill is the non-existence of studies that assess the impact of geopolitical risks on oil production despite the prevalence of geopolitical tensions in major oil producing regions. Our findings in this study will guide energy policymakers in adopting policies that relate to the effects of geopolitical shocks, risks and uncertainty, and how to curb its negative effects in the oil producing regions.

4. Research design

4.1. Data description

In investigating the determinants of crude oil production for the case of the Persian Gulf; Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. In this context, and as similarly adopted by Abdul-Manan et al. (2017), the Persian Gulf is viewed as a region (one country) rather than a panel of selected eight distinct nations. Similar to the World Bank's socioeconomic classification of countries (such as the income categorization), the implied time series estimation for the Persian Gulf is motivated by the mutual characteristics these countries share as major oil producers in the Middle East. The time series dataset consisting of the oil production, natural resources rents, geopolitical risk, and crude oil price were employed. In achieving this objective, the dataset that is restricted to the span period of 1975–2018 is considered suitable based on availability of data. The computations and further description of the employed series are given as follows:

- Oil production: This series (the dependent variable) is represented as PROD and it is the total crude oil production of Persian Gulf nations measured as thousand Barrels per Day. The source of PROD employed in this study is the United States Energy Information Administration (EIA, 2019).
- Geopolitical risk: Is employed as an explanatory variable and represented as GPR. The historical geopolitical risk index developed by Caldara and Iacoviello (2017) is employed as a proxy. Caldara and Iacoviello (2017) constructed a global monthly index of geopolitical risk and the annual average of the monthly indices for each year is calculated in this context. Their procedure involves an electronic text-search of 11 international newspapers from the archives, where they fetched articles containing words or set of terms like geopolitical risk, geopolitical tension, geopolitical uncertainty, military, war, nuclear threats, nuclear war, fear of war and terrorism among others. The number of such articles found in each month represents a share of total news articles for that month. They then normalized the index to an average a value of 100 for the 2000–2009 decade. Caldara and Iacoviello (2017) monthly index implies that a monthly reading above 100 indicates that the frequency of geopolitical risks in that month was higher than the frequency geopolitical risk in the 2000–2009 decade. If monthly reading is lower than 100, it means that geopolitical risk was less frequent in that month than the 2000s. The indices are being hosted and sourced from the website of economic policy uncertainty.[2]
- Natural resources rents: As an additional explanatory variable, the natural resources rents (represented as RENT). In this case, data on oil rent (% of GDP) have been computed from the average oil rent of the eight (8) Persian Gulf countries which were sourced from the World Bank Development Indicator (WDI, 2019).
- Average cost of damage: In this case, the cost of damage to the environment from the production of crude oil in the Persian Gulf nations is calculated from the average of energy carbon emission in the eight Persian nations. The explanatory variable is represented as ACOD and sourced from the World Bank Development Indicator (WDI, 2019).
- Crude oil price: As an additional explanatory variable, the oil price (as PRICE) is the West Texas Intermediate spot price of crude oil. The data were also sourced from US energy Information Administration (EIA).

[2] More information on the data is available at https://www.policyuncertainty.com/gpr.html; or refer to Caldara, D., & Iacoviello, M. (2017). *Measuring geopolitical risk*. Working paper, Board of Governors of the Federal Reserve Board.

Table 1
Descriptive Statistics and Cointegration test.

Properties	PROD	PRICE	GPR	RENT	ACOD
Mean	18,797.55	39.002	100.216	31.083	2.42 E+09
Median	19134.15	28.624	89.950	27.954	1.13 E+09
Maximum	26819.22	99.568	181.970	63.219	9.08 E+09
Minimum	9630.337	11.160	40.666	17.025	1.08 E+08
Std. Deviation	4410.595	26.817	39.120	10.648	2.63 E+09
Skewness	−0.228	1.088	0.426	1.155	1.187
Kurtosis	2.412	2.902	2.112	3.930	3.190
Jarque-Bera	1.015	8.698**	2.757	11.376*	10.405*
Probability value	0.602	0.013	0.252	0.003	0.006
Number of observations	44	44	44	44	44

Linear cointegration by Johansen

No. of CE(s)	Trace statistic	Critical value	P-value	Max-Eigen statistic	Critical value	P-value
None	63.481	69.819	0.144	25.260	33.877	0.368
At most 1	38.222	47.856	0.292	14.770	27.584	0.766
At most 2	23.452	29.797	0.225	13.683	21.132	0.392
At most 3	9.768	15.495	0.300	8.615	14.265	0.320

Note: ln, * and ** are respectively the logarithmic values, the 1% statistical significant level and 5% statistical significant level. Also, No. of CE(s) stands for the number of cointegration (s) equation, while PROD, PRICE, GPR, RENT and ACOD are respectively the crude oil production, crude oil price, total natural resource rent, and the average cost of damage.

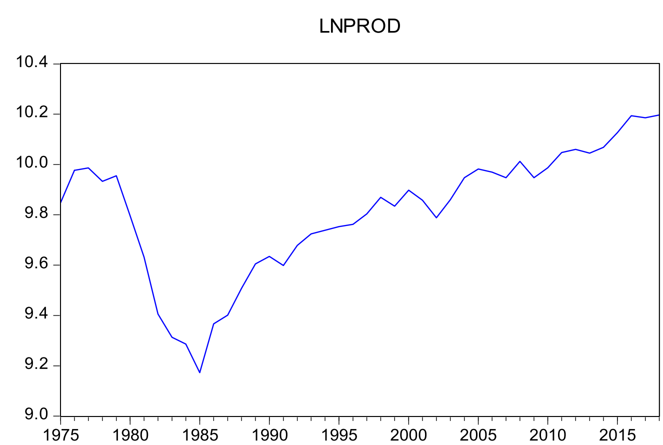

Fig. 1. The time series of the logarithm value of oil production (lnprod).

The common statistics of the dataset is presented in Table 1. The descriptive statistics shows evidence that the average cost of damage (ACOD) is presented with the highest deviation from the mean, to be followed by oil production (PROD), the GPR, PRICE and RENT. Indicatively, the trend in the volatility of the series and the virtual observation from the time series plots for each of the series (shown in Figs. 1–5) provide a relationship evidence among the variables.

4.2. Methodology

4.2.1. Empirical model

Following the seminal work of Griffin (1985) on the nexus of crude oil price and production by the Organization of Petroleum Exporting Countries (OPEC), other extant and similar studies have examined the

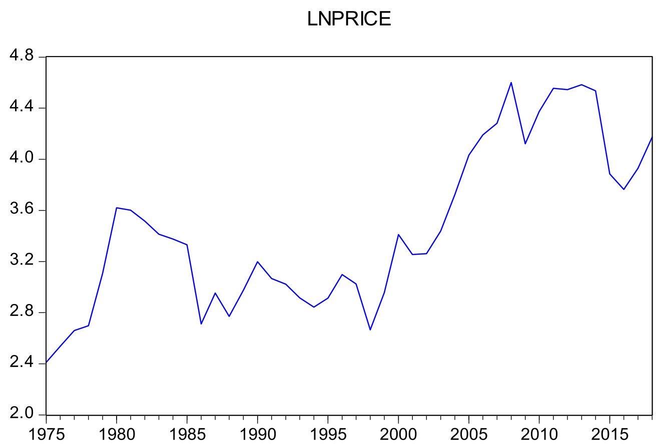

Fig. 2. The time series of the logarithm value of oil price (lnprice).

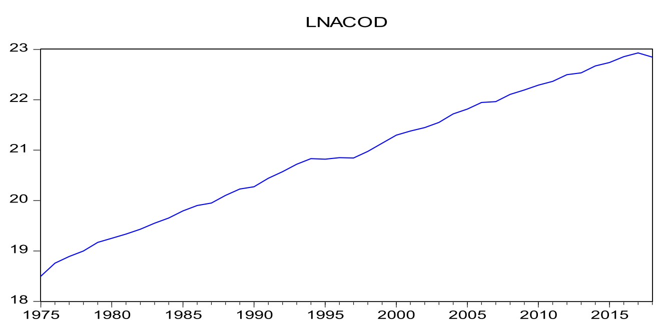

Fig. 3. The time series of the logarithm value of average cost of damage (lnacod).

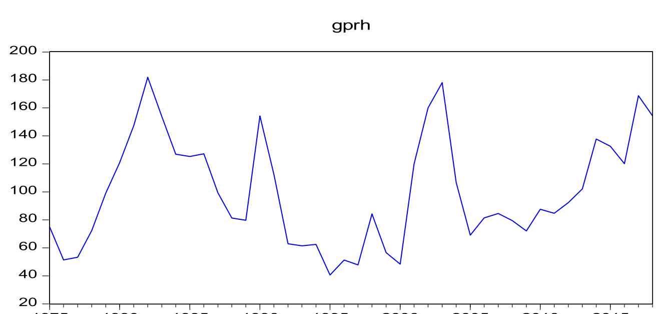

Fig. 4. The time series of the logarithm value of geopolitical risk (lngpr).

relationship between crude oil production and varying factors such as trade openness, innovation, etc. (Kaufmann et al., 2008; Al-Zayer et al., 1993; Biresselioglu and Yelkenci, 2016; Samargandi, 2019). In specific, Kaufmann and Cleveland (2001) examined and shed light on the role of average production costs in the production of crude oil especially for the lower (48) economic states. Accordingly, this study extends the works of Griffin (1985) and Kaufmann and Cleveland (2001) by considering oil price and the cost of production in the context of the environment such that oil price (PRICE) and environmental degradation factor (ACOD), in addition with other variables – geopolitical risk (GPR) and natural resources rents (RENT) are modelled as:

$$PROD_t = f(\mathrm{PRICE}_t \mathrm{GPR}_t, \mathrm{ACOD}_t, \mathrm{RENT}_t) \quad (1)$$

The stationarity of the concerned variables is investigated with the unit root test techniques (Lee and Strazicich, 2003; Dickey and Fuller, 1979). For lack of space, the step-by-step estimation procedures of the

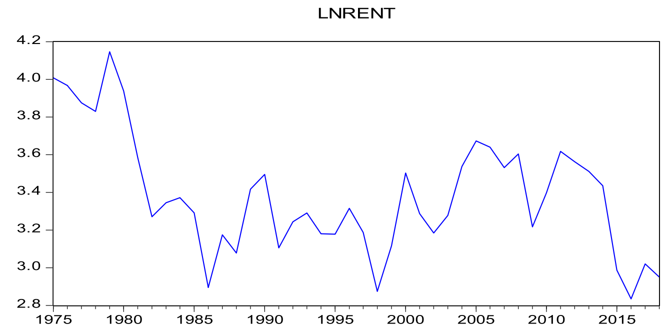

Fig. 5. The time series of the logarithm value of total natural resource rent (lnrent).

Table 2
Unit root test.

	LS		ADF	
Variable	Coefficient	Break Date	Constant	Constant with Trend
*ln*PROD	−6.657**	1991, 2000	−0.449	−1.780
Δ *ln*PROD	−5.374	−4.641*	−4.957*	
*ln*PRICE	−4.296	1990, 2008	−1.600	−2.030
Δ *ln*PRICE	−9.067*	−5.982*	−5.908*	
GPR	−4.742	1992, 2004	−2.478	−2.480
Δ GPR	−6.300***	−5.761*	−5.684*	
*ln*RENT	−5.778***	1986, 2013	−2.622***	−2.731
Δ *ln*RENT	−6.968*	−6.385*	−6.306*	
*ln*COD	−4.138	1995, 2012	−2.473	−2.940
Δ *ln*ACOD	−5.889*	−5.555*	−5.889*	

Note: The ln, Δ, *, ** and *** are respectively the logarithmic values, the first difference operator, the 1% statistical significant level, 5% statistical significant level and the 10% statistical significant level. The PROD, PRICE, GPR, RENT and ACOD are respectively the crude oil production, crude oil price, total natural resource rent, and the average cost of damage.

unit root techniques are not illustrated in this study, however, the result of the estimation is presented in Table 2. The unit root result implies that the series are all stationary at first difference i.e. I (1). By implication, potential evidence of linear long-run relationship between PROD and PRICE, GPR, ACOD, and RENT is examined by employing a feasible cointegration technique (Johansen, 1988; Johansen and Juselius, 1990). Unfortunately, the statistical evidence from the cointegration estimation suggests that there is no linear long-run relationship, thus creating the need to employ the non-linear cointegration approach.

4.2.2. The non-linear dynamic relationship

In order to investigate potential evidence of non-linear relationship between the variables, we consider the Autoregressive Distributed Lad (ARDL) methodological approaches of Pesaran and Shin (1998), Pesaran et al. (2001) and Shin et al. (2014). As such, the current study is designed accordingly;

$$\mathrm{lnP}rod = r + d_1^+ \mathrm{lnPrice}^+ + d_2^- \mathrm{lnPrice}^- + d_3^+ \ln Gpr^+ + d_4^- \ln Gpr^- + d_5^+ \ln Acod^+ + d_6^- \ln Acod^- + d_7^+ \mathrm{lnR}ent^+ + d_8^- \mathrm{lnR}ent^- + e_t \quad (2)$$

Such that ln is the logarithmic transformation of the variables where ρ represents the estimation intercept. The positive and negative impact of the explanatory variables (EXP = Price, Gpr, Acod, Rent) are of the magnitudes $d_1, d_2, d_3, d_4, d_5, d_6, d_7andd_8$ for the time period t = 1, 2, 3, …, 44. Also, the decreasing and increasing negative and positive partial sum of the explanatory variables (EXP = Price, Gpr, Acod, Rent) are from the following decomposition

Table 3
Dynamic asymmetric ARDL.

Variable	Coefficient	P-value	Variable	Coefficient	P-value
*ln*PROD $^{(-1)}$	−0.480*	0.000	Constant	5.095*	0.000
*ln*PRICE+$^{(-1)}$	−0.082	0.203	Δ *ln*PRICE+$^{(-1)}$	0.044	0.697
*ln*PRICE-$^{(-1)}$	−0.626*	0.000	Δ *ln*PRICE-$^{(-1)}$	−0.580*	0.000
GPR $^{+(-1)}$	−0.043	0.437	ΔGPR $^{+(-1)}$	−0.102*	0.002
GPR $^{-(-1)}$	0.021	0.758	ΔGPR $^{-(-1)}$	−0.052	0.463
*ln*RENT $^{+(-1)}$	0.584**	0.010	Δ*ln*RENT $^{+(-1)}$	0.227***	0.083
*ln*RENT - $^{(-1)}$	0.560**	0.012	Δ*ln*RENT - $^{(-1)}$	0.416*	0.000
*ln*ACOD $^{+(-1)}$	−0.232	0.304	Δ*ln*ACOD $^{+(-1)}$	−0.459**	0.030
*ln*ACOD-$^{(-1)}$	−2.243	0.503	Δ*ln*ACOD-$^{(-1)}$	−0.538	0.439
Long-run (Asymmetry)					
*ln*PRICE $^{(+)}$	−0.171	0.240	*ln*PRICE $^{(-)}$	1.303*	0.000
GPR $^{(+)}$	−0.090	0.460	GPR $^{(-)}$	−0.043	0.762
*ln*RENT $^{(+)}$	1.219**	0.036	*ln*RENT $^{(-)}$	−1.166*	0.001
*ln*ACOD $^{(+)}$	−0.484	0.339	*ln*ACOD $^{(-)}$	4.674	0.502
Long-run (Wald test symmetry)			Short-run (Wald test symmetry)		
*ln*PRICE	19.72*	0.000	*ln*PRICE	3.154***	0.096
GPR	0.356	0.559	GPR	2.728	0.119
*ln*RENT	0.005	0.943	*ln*RENT	0.861	0.368
*ln*ACOD	0.362	0.557	*ln*ACOD	0.569	0.462

Note: The ln, Δ, *, ** and *** are respectively the logarithmic values, the 1% statistical significant level, 5% statistical significant level and the 10% statistical significant level. The PROD, PRICE, GPR, RENT and ACOD are respectively the crude oil production, crude oil price, total natural resource rent, and the average cost of damage. Also, the (+) and (−) are the respective positive and negative impacts.

$$EXP_t^+ = \sum_{i=1}^{t} \Delta EXP_i^+ = \sum_{i=1}^{t} \max(\Delta EXP_i, 0), EXP_t^- = \sum_{i=1}^{t} \Delta EXP_i^- = \sum_{i=1}^{t} \min(\Delta EXP_i, 0) \tag{3}$$

By proceeding with the modifications of linear ARDL using the functional form (equation (2)) in consolidation with equation (3), the non-linear ARDL of Shin et al. (2014) can now be represented as

$$\begin{aligned}\Delta \mathrm{Prod}_t = \gamma + \theta \mathrm{Prod}_{t-1} + \beta_1^+ \mathrm{Price}_{t-1} + \beta_2^- \mathrm{Price}_{t-1} + \beta_3^+ Gpr_{t-1} + \beta_4^- Gpr_{t-1} + \beta_5^+ Acod_{t-1} + \beta_6^- Acod_{t-1} + \beta_7^+ \mathrm{Rent}_{t-1} + \beta_8^- \mathrm{Rent}_{t-1} \\ + \sum_{i=0}^{q} \phi_2 \Delta \mathrm{Price}_{t-1}^+ + \sum_{i=0}^{q} \phi_3 \Delta \mathrm{Price}_{t-1}^- + \sum_{i=0}^{q} \phi_4 \Delta Gpr_{t-1}^+ + \sum_{i=0}^{q} \phi_5 \Delta Gpr_{t-1}^- + \sum_{i=0}^{q} \phi_6 \Delta Acod_{t-1}^+ + \sum_{i=0}^{q} \phi_7 \Delta Acod_{t-1}^- + \sum_{i=0}^{q} \phi_8 \Delta \mathrm{Rent}_{t-1}^+ + \sum_{i=0}^{q} \phi_9 \Delta \mathrm{Rent}_{t-1}^- + \varepsilon_t\end{aligned} \tag{4}$$

The steps involved in estimating non-linear relationship as expressed in equation (4) involves (1) the estimation of the ordinary least square, (2) the estimation of the long-run relationship between PROD and each of PRICE $^{(+)}$, PRICE $^{(-)}$, GPR $^{(+)}$, GPR $^{(-)}$, ACOD $^{(+)}$, ACOD $^{(-)}$, RENT $^{(+)}$, and RENT $^{(-)}$. Consequently, the Shin et al. (2014) approach is adopted to test the aforementioned relationships through the following approach: (a) testing the null hypothesis of no cointegration:$\beta = \beta^+ = \beta^- = 0$, F-statistic (against the alternative of cointegration) of bound-testing, (b) examine the short-run ($\varphi = \varphi^+ = \varphi^-$) and long-run ($\beta = \beta^+ = \beta^-$) symmetry by employing the standard Wald test, and (c) the asymmetric cumulative dynamic multiplier effect is examined as a diagnostic test from the following expression (5a, 5 b, 5c, and 5 d)

$$m_a^+ = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial \mathrm{Price}_t^+}, m_a^- = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial \mathrm{Price}_t^-} \tag{5a}$$

$$m_a^+ = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial Gpr_t^+}, m_a^- = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial Gpr_t^-} \tag{5b}$$

$$m_a^+ = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial Acod_t^+}, m_a^- = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial Acod_t^-} \tag{5c}$$

$$m_a^+ = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial \mathrm{Rent}_t^+}, m_a^- = \sum_{j=0}^{a} \frac{\partial \mathrm{Prod}_{t+j}}{\partial \mathrm{Rent}_t^-} \tag{5d}$$

From equations (4) and (5a, 5b, 5c, and 5d), the long-run asymmetric coefficient is estimated as $\kappa^+ = -\frac{\beta^+}{\gamma}, \kappa^= = -\frac{\beta^-}{\gamma}$ where $\kappa^+ = m^+$ and $\kappa^= = m^-$, given that $a \rightarrow \infty$.

Given the aforementioned estimation procedure, the result of the non-linear autoregressive distributed lag is presented in Table 3.

5. Findings and discussion

Foremost, the impact of geopolitical risk, indicated as GPR, in addition to the other explanatory variables is implied in Table 3. For the price of crude oil, the impact of positive shock on the previous year's value of crude oil price in both the long run and short-run exerts a non-significant and positive effect on the production of crude oil. However, when there is a negative shock in the previous price of crude oil, the effect on the crude oil production in both the long-run and short-run is significant and negative. In specific, a negative shock is estimated to cause 0.62% long-run decline and 0.58% short-run decline in the oil production. Indicatively, this is a possible occurrence especially when there is a serious oil glut in a preceding year. Similarly, while the positive shock in the oil price has no significant evidence on oil production in the long-run, a negative shock is observed to cause a positive and significant impact (an increase of 1.30%) in the short-run. However, in terms of the symmetric relationship, a percentage increase in the price of crude oil will cause a positive increase in the production of the commodity by 19.72% and 3.15% in the long-run and short-run respectively. The asymmetric effect of oil price on oil production is synonymous to the up and down effects of the crude oil price on the economy as illustrated in previous studies (Mork et al., 1994; Ferderer, 1996; Caldara et al., 2019).

Although there is sparse literature on the nexus of natural resources rents (RENT) and oil production, the current study establishes the asymmetric relationship. While affirming the existence of the RENT-PROD nexus, this study found that the previously imparted shocks (both positive and negative) on the natural resources rents exerts a statistically significant and positive impact on crude oil production of

Table 4
Diagnostic test (NARDL).

Breusch/Pagan heteroskedasticity test = 0.259 (0.611)	Ramsey (RESET) test = 0.659 (0.593)
Normality (Jarque-Bera) test = 0.869 (0.648)	Portmanteau test = 25.61 (0.152)
R-squared = 0.932	Adjusted R-squared = 0.813
F-statistics (26, 15) = 7.870 (0.0001)	Root Mean Square Error = 0.034

Note: RESET is Regression Equation Specification Error **Test**.

the Persian Gulf countries in the long-run and short-run. Specifically, when there is a positive (negative) shock, a one percent increase in the previous value of RENT i.e. (lag of RENT) will cause a statistically significant increase in production of crude oil by 0.58% (0.56%) in the long-run and about 0.23% (0.42%) in the short-run. It therefore implies that oil production will always increase irrespective of either positive or negative shock on the natural resources rents. However, a positive and negative shock on RENT is responsible for a respective positive (+1.219) and negative (−1.166) impact in the long-run.

Concerning the impact of the geopolitical risk (GPR) and the average cost of damage (ACOD) on oil production, the long-run impacts resulting from the positive and negative shocks in the previous year's values of the GPR and ACOD are not statistically significant on the crude oil production. However, a positive shock in the previous year's values of GPR and ACOD are responsible for a decrease in the crude oil production in the short-run. Indicatively, under positive shocks, a percentage increase in GPR will cause a decline in oil production by about 0.1%, while a percentage increase in ACOD, when in the presence of a positive shock, will cause 0.46% decline in crude oil production in the short-run. This translates to the fact that when there is an increase in the geopolitical risk in the Persian Gulf region or there is an increase in the cost of damage (possibly) due to environmental degradation, the resulting effect will be a significant decline in the production of crude oil. This also imply that the positive impact of reduced geopolitical risk will not be significant and will not have same magnitude of relief as the negative impact caused when geopolitical risk spikes up. The aforementioned result is a true and common reflection associated with oil production in the Persian Gulf countries and in most of the oil rich states such as Libya, Nigeria, Sudan, Venezuela and others. Evidently, situations such as the frequent disruption of oil transportation through the Strait of Hormuz, Suez Canal and oil spillage (see Deepwater Horizon/Gulf of Mexico oil spill) characterized the impact of both geopolitical risk and cost of damage on oil production (Morse and Richard, 2002; Encyclopedia Britannica, 2020).

5.1. Diagnostic test

About the diagnostic check of the estimation, the normality, serial correlation and heteroskedasticity are all indicated in Table 4, while the cumulative effects from each of the explanatory variables to crude of production is implied in Fig. 6. With the estimation of the non-linear ARDL, there is no concern resulting from heteroskedasticity and serial correlation because of the failure to reject the null hypothesis for homoscedasticity (Breusch/Pagan heteroskedasticity test = 0.259) and no serial correlation (Ramsey (RESET) test = 0.659) are both not rejected. While there is a statistical significant normal distribution of the estimated variables, evidence further implies that, the explanatory variables explain the properties of oil production by about 93.2% and with an error of 0.034. In addition, the results in Table 3 were virtually affirmed by the illustrations in Fig. 6 such that the negative shock on PRICE and ACOD evidently dominates the positive shocks in the overall asymmetry. While the positive shock on the GPR is evidently more influencing than the negative shock, there is no overbearing effect of either the positive or the negative shock on each other in the natural resources rents (RENT).

6. Concluding remark and policy insight

Consisting of eight countries (Bahrain, Iran, Iraq, Kuwait, Oman,

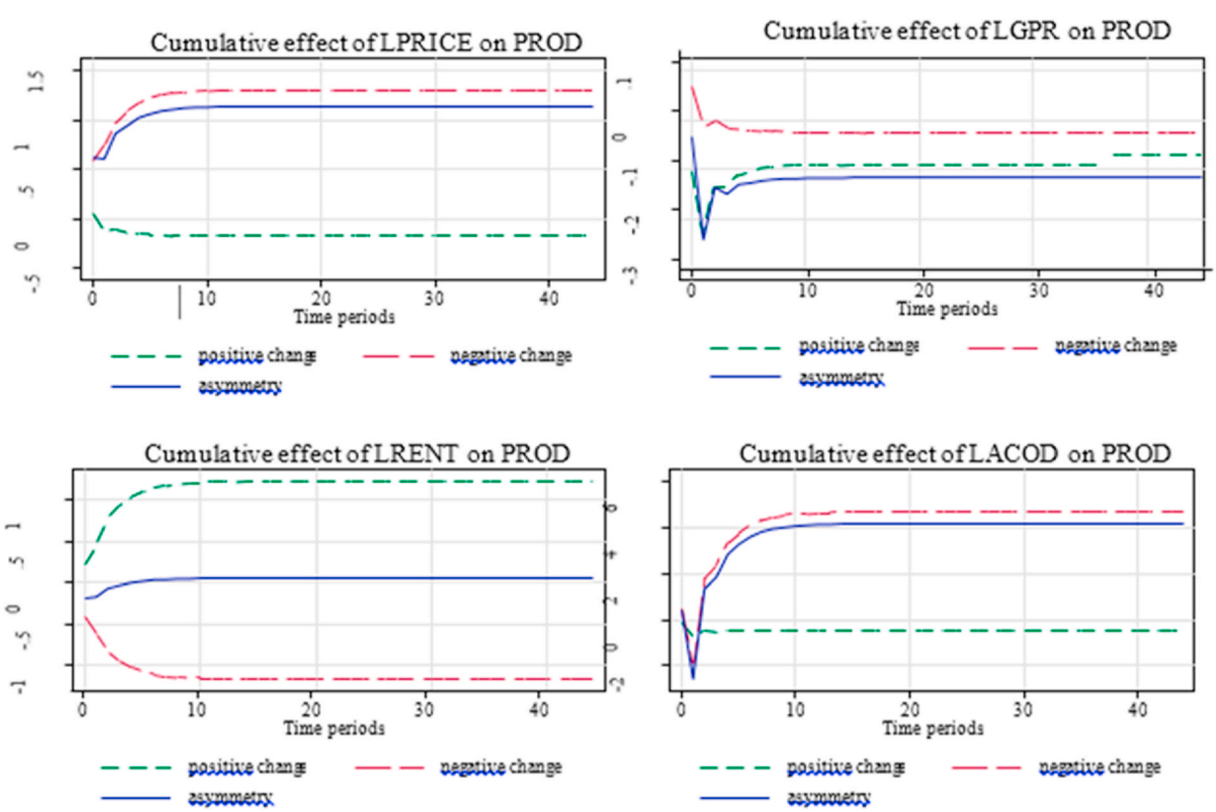

Fig. 6. The cumulative effect among the estimated variables.

Qatar, Saudi Arabia, and the United Arab Emirates), the Persian Gulf region is synonymous with crude oil, and largely, huge deposit of hydrocarbon fuel. Considering the strategic location of the countries, the incessant tension amid other driving factors of crude oil production in and around the Middle East and the Persian Gulf region, this study further explore the determinants of oil production. We achieved the outlined objective of the study, the role of geopolitical risk, total natural resources rents, average cost of damage and the crude oil price on the production of crude oil in the Persian Gulf states, by employing the nonlinearity technique of the Autoregressive Distributed Lag (NARDL).

The study found a significant impact of the negative shock in the previous year's value of oil price on oil production in both the long run and short-run. Additionally, the negative shock in oil price has an asymmetric and significant impact on oil production while the symmetric impact of price is statistically significant in both long run and short-run. Similarly, both the previous year's values of the average cost of damage and geopolitical risk negatively affect the production of crude oil in only in short-run when there is a positive shock on both. Moreover, the impact of the previous year's value of the natural resources rents on production of crude oil is positive in both the long run and short-run in either a positive or negative shock scenario. Meanwhile there is a significant and asymmetric impact of resources rent on oil production when the shock is negative in the long run.

Regarding policy, the current study offers feasible policy directions for implementation. Considering that geopolitical risk arising from the regional tensions is capable of causing a dwindling crude oil production and subsequently causing economic downturn, peace and resolution framework should be advanced by the member countries. While promoting the interest of each member state, effort of the states should be devoted to economic and political activities that promote harmony and at the same time minimizing external threats. It is also necessary to maintain this peace because the non-significance of the negative shocks to geopolitical risk is an indication that a decline in geopolitical tension after an adverse event does not necessarily imply an increase in oil production afterwards. Similarly, environmental regulations amidst security and insurance framework could be strengthened to accommodate the protection of oil installations and the crude oil transportation route such as the Strait of Hormuz and the Suez Canal. Such policy is deemed appropriate for other related cases to avert further oil damage like the oil spillage (known as Deepwater Horizon/Gulf of Mexico oil spill). Finally, the administration of resource rents should also be an essential part of economic policy in the oil rich countries since this has positive impact on oil production whether under negative or positive shocks.

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CRediT authorship contribution statement

Ifedolapo Olabisi Olanipekun: Data curation, Writing - original draft. **Andrew Adewale Alola:** Writing - review & editing, Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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