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Shale oil revolution: Implications for oil dependent countries

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Abstract

The International Energy Agency (IEA) recently announces that the explosive increases in the United States oil output, particularly from shale oil, would make the country become world's top oil producer and eventually exporter ahead of Saudi Arabia and Asia in the coming years. Motivated by this projection, we therefore examine the implications of the US shale oil on oil exports of OPEC and selected non-OPEC countries using the Structural Vector Autoregressive (SVAR) approach. Our results reveal that the US oil supply shocks particularly those due to shale oil are critical in the output and supply decisions of OPEC and major non-OPEC oil exporters. Underestimating the potential consequences of US overtaken the current world oil giants and failure to put in place critical structural shifts by these countries, especially alternative revenue sources, pose a potential threat to their growth prospects.

JEL classification: E31, E32, Q31, Q43

Keywords: Shale Oil, Crude Oil, Oil Supply Shocks, OPEC, Shale Revolution

Shale oil revolution: Implications for oil dependent countries

1.0 Background

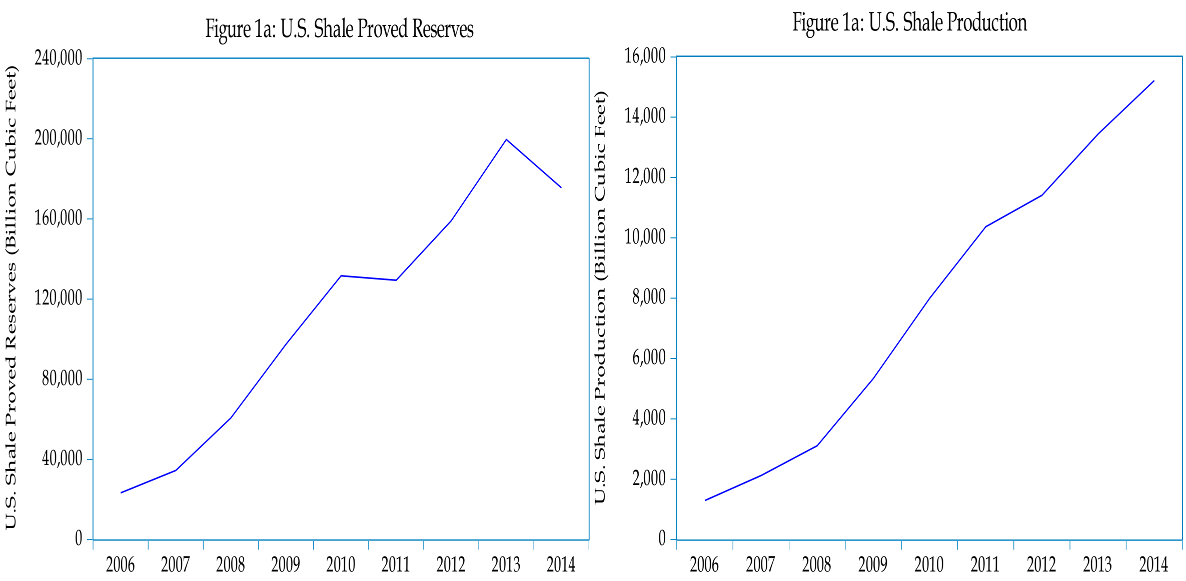
The emergence of shale oil as a major energy resource and competitor to conventional oil has created a great deal of delight and anxiety in the energy world for both producers and consumers. The US highlight of the role of shale formations and other tights as sources of crude oil, lease condensates, and other varieties of liquids processed from wet natural gas such as ethane, propane, butane, isobutane and natural gasoline further amplify the trepidation. Shale oil and gas technology has further steered the development of more resources at lower costs. In particular, unconventional gas reflected more than 10% of global gas production in 2014 and its entrant into the global energy market disrupts the global supplier landscape and creates increased competition in regional natural gas markets (World Energy Council [hereafter WEC], 2016). Besides, the exploration of shale resources, most especially by US, China and other conventional oil importing giants, could pose further threats to current conventional oil exporting economies.

In the past, the focus on shale oil and gas exploration and production has been mainly in North America, particularly the United States and Canada. The US shale proved reserves rose from 23,304 billion cubic feet (Bcf.) in 2007 to 199,684 Bcf. in 2014 but declined by about 12% to 175,601 Bcf. in 2015 (see Figure 1a). On the other hand, the US shale production has continued to increase over the years (see Figure 1b). The shale production figures released by the US Energy Information Administration (EIA) in 2016 show an increase in production by about 1,076% between 2007 and 2015.

The interest in shale oil and gas exploration and production has also spread to other countries. For example, Argentina and China have also been producing shale gas on commercial scale. The potential for many nations also seems very promising. In

2011, Advanced Resource International (ARI), a private consulting, research and development firm conducted the first global study on shale gas resources in 48 basins across 32 countries (excluding the US)[1]. The total number of formations stood at 69 with technically recoverable shale gas at 6,622 trillion cubic feet (Tcf.) and 32 billion barrels (Bbl.) of shale tight oil. Two years after the first report, the global shale gas resource estimate was 10 percent higher than the previous findings. The number of basins and countries increased to 95 and 41 respectively, with the new total number of formations at 137.

Figure 1: US Shale Proved Reserves and Production (2007 – 2015)



Empirically, the shale oil revolution is found to impact on oil price (Bataa and Park, 2017; Monge et al., 2017) and has increased competition in the crude oil market (Ansari, 2017; Behar and Ritz, 2017). Meanwhile, there is evidence that the most of the expected increases in US oil supply due to the shale oil revolution has already been incorporated into prices and therefore will have minimal impact on the GDP of oil importers in the period 2010–2018 (Mănescua and Nuño, 2015). In this paper, we also contribute to the growing debate on shale oil revolution by analysing its quantitative effects on the oil dependent nations including OPEC and non-OPEC oil

[1] The report was released as part of US Energy Information Administration report is titled "World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States".

exporting countries. We offer some insightful results that are yet to be documented in the literature with regard to shale oil production.

The remaining sections of the paper are organized as follows. In Section 2, we render some trends in oil production and export. The estimable model and the econometric methodology are presented in Section 3 while the results are discussed in Section 4. We offer some policy implications in Section 5 while Section 6 concludes the paper.

2.0 Trends in oil production and export: US vs OPEC and Non-OPEC

The emergence of unconventional oil and gas as well as increase in its production has brought about structural changes in the global oil and gas industry. The industry has witnessed emergence of non-OPEC supply. Particularly, the US shale oil revolution has attracted a lot of attention in global energy discussion, with some sources predicting that the US will overtake countries like Saudi Arabia and Russia to become the World's largest oil producer by 2020 (IEA, 2012). Crude oil has been a major dominance in global energy mix in the wake of the Second World War. The 2016 estimates of the world's proven crude oil reserves show that 1,216.78 B bbl. which is about 81.5% of the total reserves are located in OPEC member states. The remaining 18.5% is spread across non-OPEC member states. However, reports that the shale boom could make US become the world's biggest producer and eventually exporter of oil have proliferated the news and as such it calls for concerns and proactive measures, especially by monolithic oil-dependent economies. Although in the interim, crude oil remains irreplaceable in the global energy mix as most alternative energy sources are expensive and less versatile. For example, the world's total estimated demand for oil for 2016 stood at 92.9 million barrels per day while the total oil supply is about 87.91 million barrels with only 1 percent of the global supply from shale oil (Salameh, 2013).

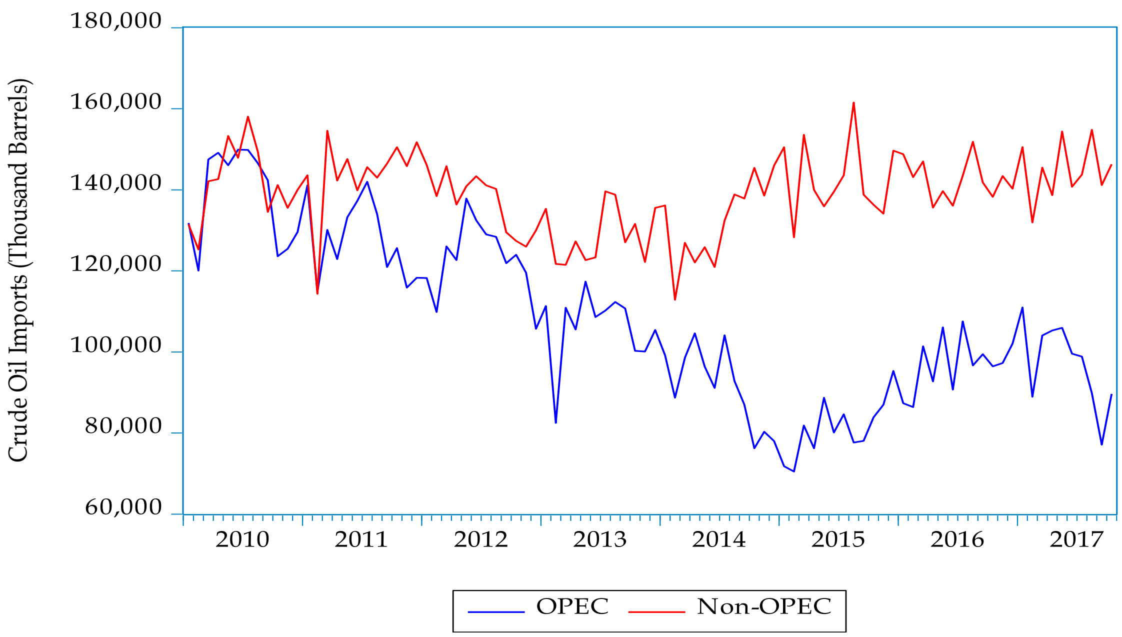
OPEC's crude oil production remains dominant in the global crude oil production hovering above 40 per cent for more than two decades. However, at the end of 2016 the Unites States alone produced approximately 8.9 million barrels of crude oil daily which is about 12 per cent of global production and third largest producer in the world after Saudi Arabia and Russia. US production has continued to be on the increase in recent times (See Table 1). Besides, the share of crude oil in the US oil supply mix is becoming less important. For example, the crude oil share of oil supply which stood at about 88 per cent in 1960 has constantly reduced to around 67 per cent at end of 2016. Notable among the cause of the declining importance of crude oil in the US include the decline in crude oil production, boom in tight oil production, and the steady increase of non-crude elements — such as natural gas liquids mainly extracted from non-crude elements especially from biofuels (OPEC, 2017).

Table 1: Crude Oil Production: OPEC and US

Period	2012	2013	2014	2015	2016
OPEC	32,666 (45%)	31,830 (44%)	30,909 (42%)	31,850 (42%)	33,281 (44%)
US	6,487 (9%)	7,468 (10%)	8,764 (12%)	9,415 (13%)	8,875 (12%)
World	72,699 (100%)	72,862 (100%)	73,436 (100%)	75,123 (100%)	75,477 (100%)

Note: Percentage of global production in parenthesis

Figure 2: US Crude Oil Imports (OPEC & NON-OPEC)



Despite its growing production of oil, the US still remains a net importer of oil. According to the US EIA, as a result of declining oil consumption, increased used of biofuels and increased domestic production, the US petroleum imports which peaked in 2005 have generally been declining with less and less imports from OPEC countries (see Figure 2). Perhaps as a result of increased imports of petroleum products from the US[2], Canada is now the largest source of US petroleum imports. US imports 38 per cent of her total crude oil imports from Canada in 2016, more than imports from entire OPEC countries which is about 34 percent.

3.0 The Model

We begin the empirical estimation by evaluating a baseline model of Kilian (2009) that comprises the global oil market production (wrd), US real economic activity (measured using US index of industrial production, ipi) and the real price of oil, which is measured using the West Texas Intermediate price of crude oil (wti). Kilian (2009) proposes a contemporaneous ordering restrictions to identify oil supply shocks, economic aggregate demand shocks and oil market specific demand shocks. The structural VAR representation is written as:

$$A_0 z_t = \beta + \sum_{i=1}^{p} A_t z_{t-i} + \varepsilon_t \qquad [1]$$

where z_t is the vector of variables, ε_t denotes the vector of serially and mutually uncorrelated structural innovations with variances of world oil supply shock [1], US aggregate demand shock [2] and oil specific demand shock [3], $\varepsilon_t = \left(\varepsilon_t^1, \varepsilon_t^2, \varepsilon_t^3\right)$ and A_0 is a lower-triangular matrix in the equation. Since A_0^{-1} is assumed to have a recursive structure, therefore, the reduced form errors e_t can be decomposed into $e_t = A_0^{-1}\varepsilon_t$

$$e_t = \begin{pmatrix} e_t^{wrd} \\ e_t^{ipi} \\ e_t^{wti} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{global\ oil\ supply\ shock} \\ \varepsilon_t^{US\ aggregate\ demand\ shock} \\ \varepsilon_t^{oil-specific\ demand\ shock} \end{pmatrix} \qquad [2]$$

[2] For instance, in 2016, the total petroleum products export from the US to Canada is about 18 percent of the total petroleum exports.

The temporal patterns of responses to the shocks could be represented as a vector moving average representation of the above SVAR model and can be derived as:

$$z_t = \left(\sum_{i=0}^{p} A_i^* L^i\right)^{-1} \varepsilon_t = \left(\sum_{k=0}^{\infty} \Phi_k L^k\right) \varepsilon_t = \sum_{k=0}^{\infty} \Phi_k \varepsilon_{t-k} \qquad [3]$$

where $A_0^* = A_0$, $A_0^* = -A_i$, $i = 1,..., p$ and elements of the *j*th column of Φ_k give the vector of the impulse response functions (IRFs) for a unit shock to the *j*th element of z_t at horizon k. The historical decomposition of the *i*th element of z_t is also given as

$$z_t = \sum_{j} \sum_{k=0}^{\infty} \Phi_{i,j}^{(k)} \varepsilon_{i,t-k} \qquad [4]$$

where $\Phi_{i,j}^{(k)}$ is row i and column j of Φ_k, and $\varepsilon_{j,t}$ is the *j*th element of ε_t. As noted in the introduction, the question of considerable interest is how the structural innovations in US oil supply relate to OPEC and selected non-OPEC oil supply. To achieve this, we construct a structural VAR model similar to equation [1] to evaluate the responses of OPEC and non-OPEC crude oil supply to US oil supply. Following the findings in Kilian (2009), oil prices must be treated endogenously in modelling the global oil market. Besides, the same methodology has been recently employed by Bataa and Park (2017) to examine the relationship between oil price and US shale revolution. Therefore, the vector of variables is modified to include US oil production (crude oil and oil shale), OPEC and non-OPEC crude oil supply and oil price.

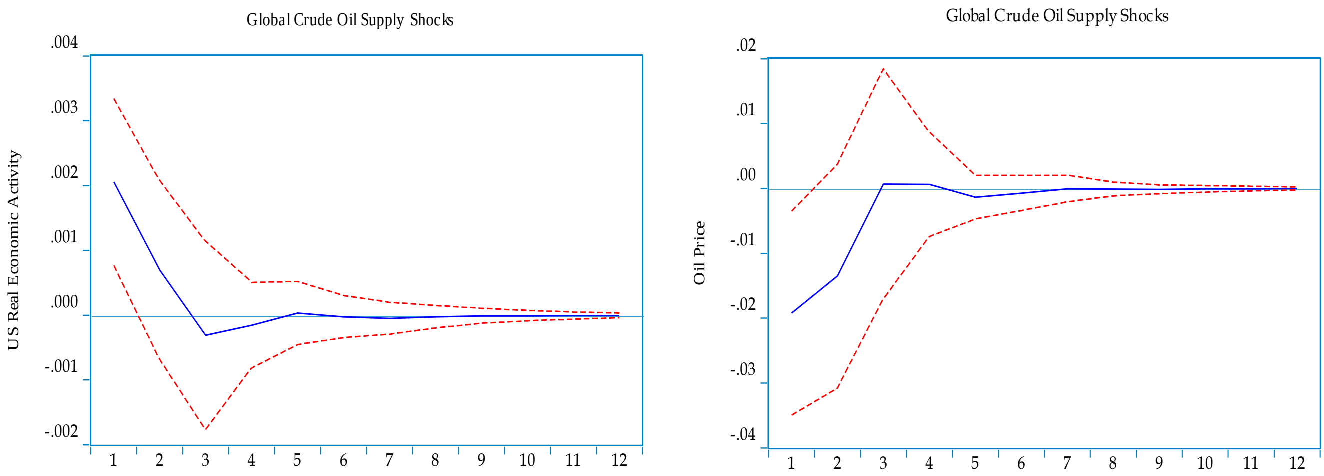
4.0 Discussion of Results

4.1 Effects of shocks to global crude oil supply on crude oil price and US economic output and

We begin the empirical discussion by considering a baseline estimation of the impact of the shocks to global crude oil supply on the real economic activity of the US and the price of crude oil. The idea is to first establish that the constructed model is valid for subsequently analyses on the basis of how well the resulting impulse responses are able to predict reality. Figure 3 shows the impulse responses of US real economic activity and global price of crude oil to shocks in global production of crude oil.

While the shock to global crude oil supply seems to have a decreasing effect on the level of real economic activity in the US, it however portends an increasing effect for oil price. This is quite understandable as global crude oil shock tends to slow down the demand for crude and by implication real economic activity owing to the upward trend in crude oil price as a result of the shock. We are therefore quite confident about the plausibility of the constructed SVAR model for the main analyses as presented in immediate succeeding sections.

Figure 3: Impulse responses of US real economic activity and oil price to crude oil supply shocks

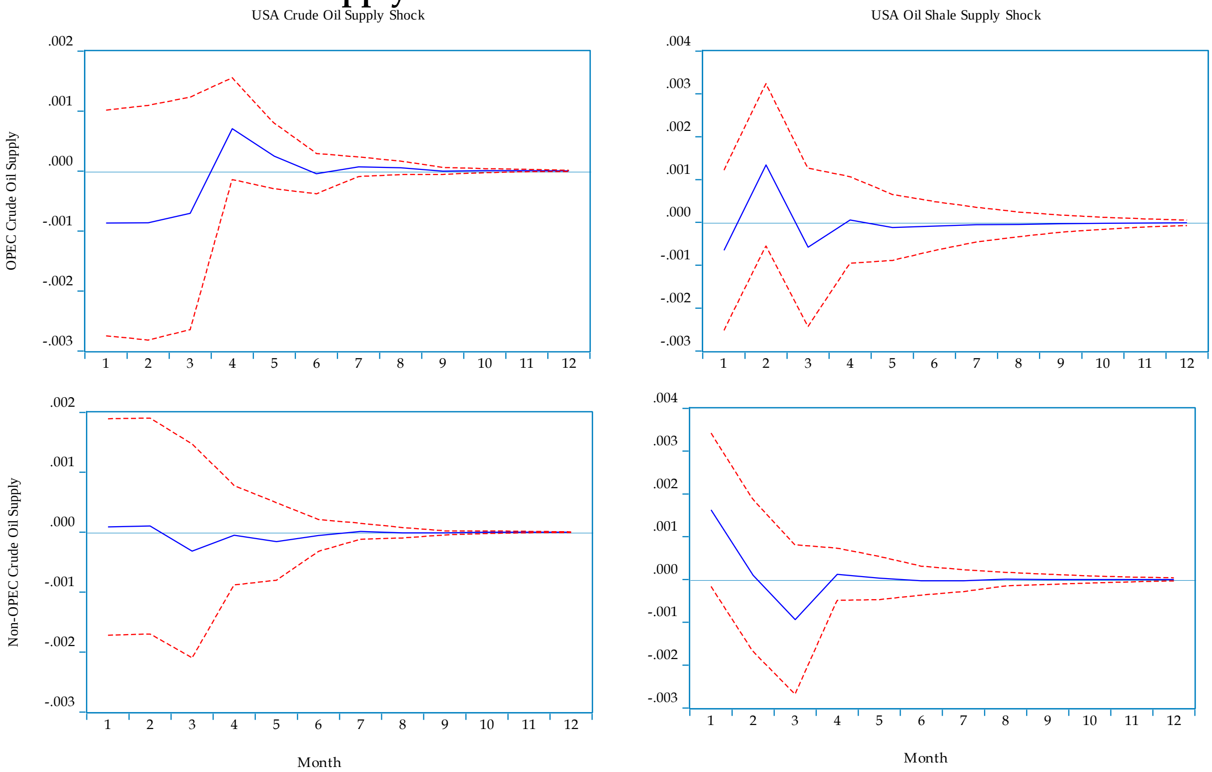


4.2 Responses of OPEC and Non-OPEC to US oil supply shocks

We further analyse the responses of OPEC and Non-OPEC to US oil supply shocks which constitutes one of the main objectives of this study. The upper panel of Figure 4 shows the impulse responses of OPEC to shocks due to US crude oil and oil shale supply respectively while the lower panel of the figure deals with the Non-OPEC group. Unexpected disruptions in the oil market as a result of US crude oil supply have significant effect on the cumulative crude oil supply of OPEC and non-OPEC member countries. Shocks to US crude oil production leads to initial negative responses by OPEC countries with decline in their output. However, a positive response is noticeable at about the 4th month with an increase in OPEC crude oil supply in response to increased US crude oil production. Albeit, the supply behaviour of OPEC to shocks in shale output is not stable.

For the non-OPEC countries, the impulse responses are shown in the lower panel of Figure 4. We find that the magnitude of impulse responses of Non-OPEC countries to shocks in US crude oil supply is less substantial when compared with that of OPEC. While the decline in OPEC supply is larger as a result of US increased crude production and persists for about six months based on one-standard error bands, the response by Non-OPEC members is trifling and lasts for only four months. Contrary to the Non-OPEC trivial impulse responses to the shocks in US crude oil supply, the impulse response from same to shocks due to US oil shale supply is substantial and it begins to level off at the end of the fourth month. This suggests that the Non-OPEC group appears to respond more to shocks due to oil shale than their OPEC counterparts.

Figure 4: Impulse Responses of OPEC and Non-OPEC Oil Supply to Shocks in US Oil Supply



We further evaluate the response of individual member countries of OPEC and some non-OPEC to shocks due to US crude oil and shale supply. The impulse responses of each country are presented in Figures 5 to 8. Perhaps because these countries belong to the same group or as a result of output and supply regulations by countries in the OPEC cartel, the response of these countries to US oil supply shocks tend to exhibit similar features. For instance, all the individual OPEC member countries considered, except Ecuador and Venezuela, respond negatively to shocks in US crude oil supply. Although the magnitude of the response differs for all the countries, this initial response is followed by an increase in supply of crude oil for countries like Angola, Gabon, Iran, Libya, Nigeria, Qatar and United Arab Emirate. However, for Algeria, Ecuador, Iraq and Saudi Arabia, there is decline in their crude oil supply. In a similar vein, from the non-OPEC country list, Canada and Norway respond to shocks due to US oil supply positively. On the other hand, Russia crude oil supply responds negatively to shocks in US oil supply. However, the effects of the shock counter-balance quickly compared to the two other non-OPEC countries (See Figures 5 to 8).

Figure 5: Impulse Responses of OPEC Members Oil Supply to Shocks in US Crude Oil Supply

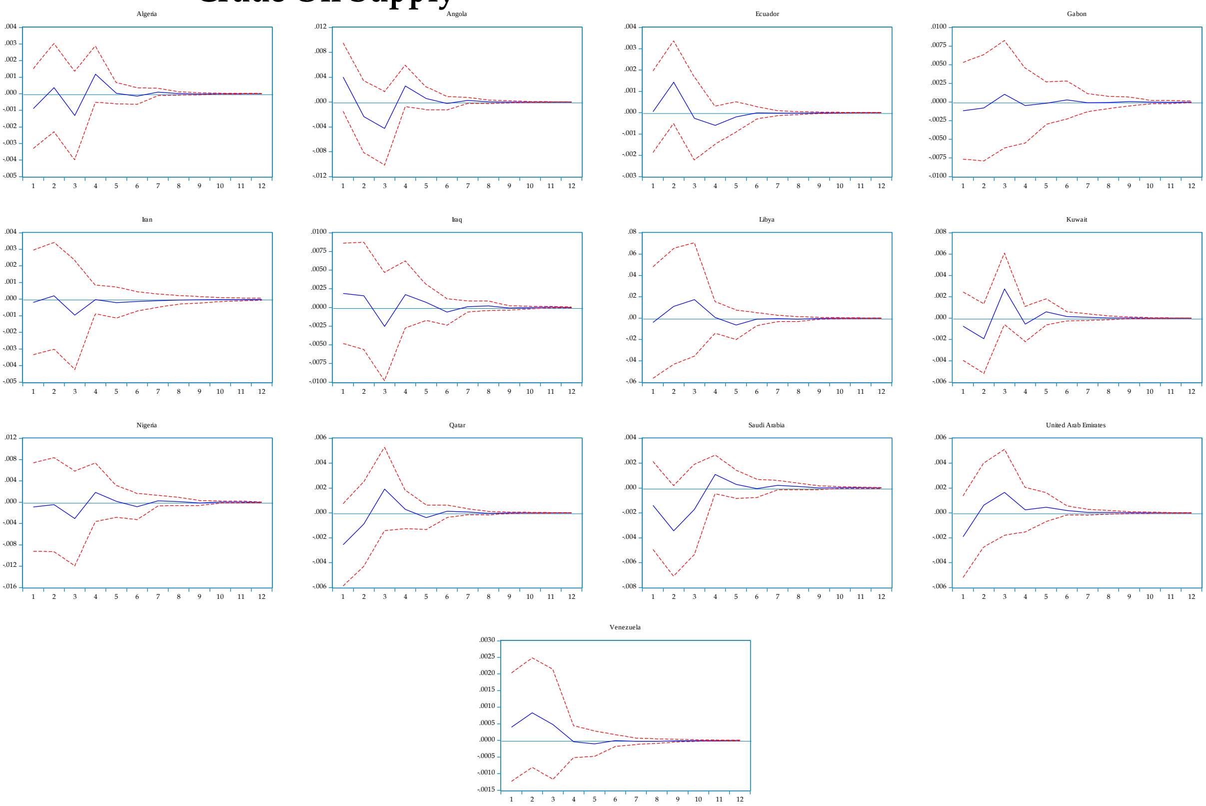


Figure 6: Impulse Responses of Selected Non-OPEC Members Oil Supply to Shocks in US Crude Oil Supply

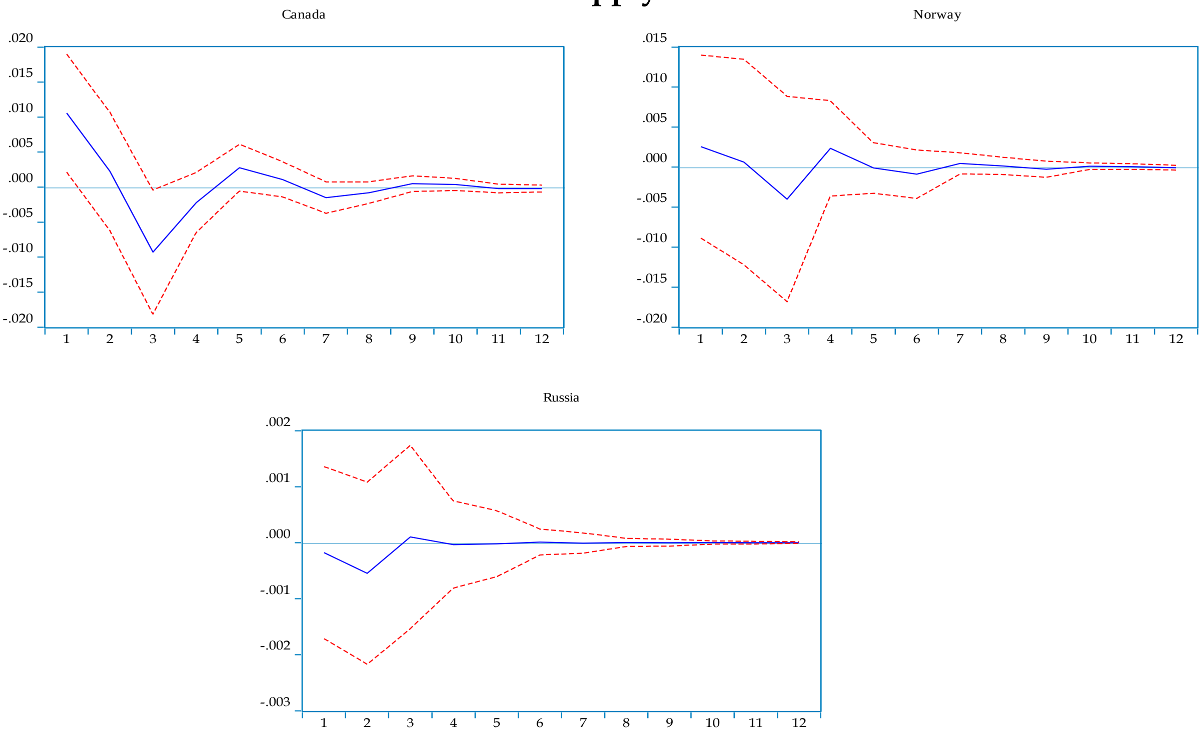


Figure 7: Impulse Responses of OPEC Members Oil Supply to Shocks in US Oil Shale Supply

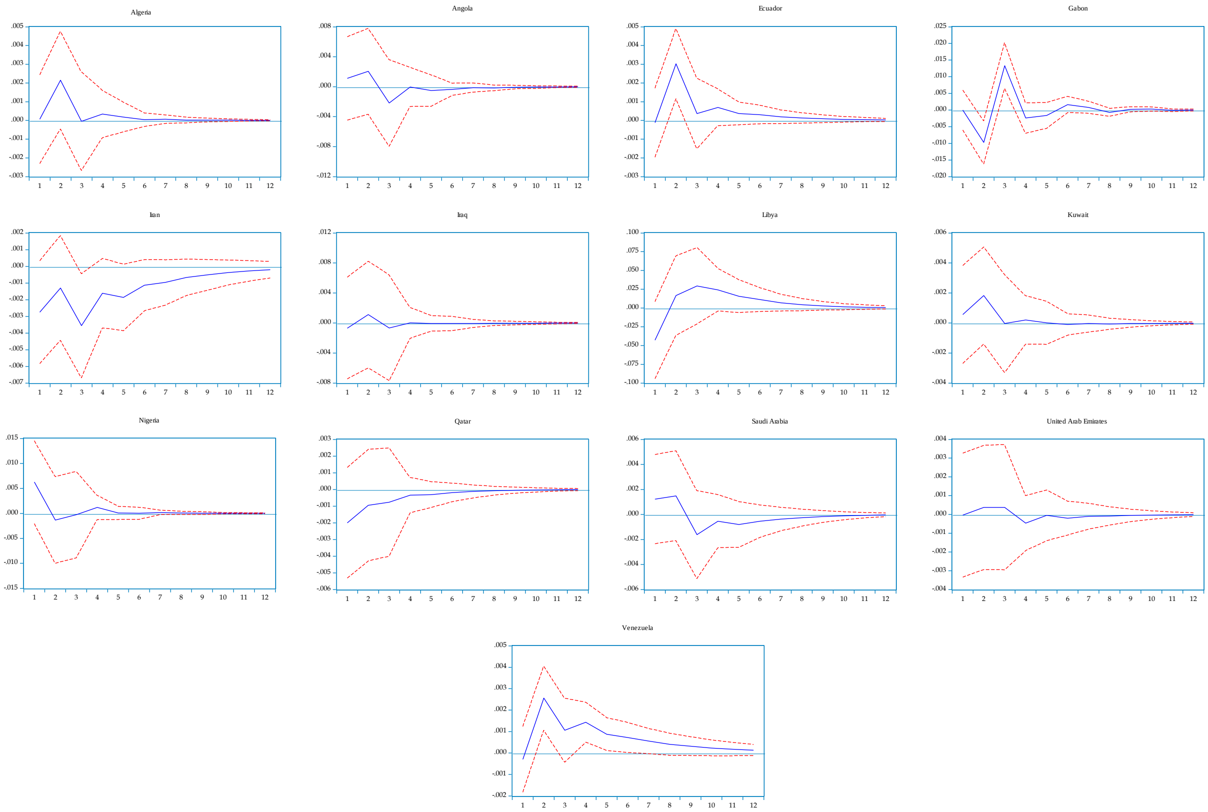
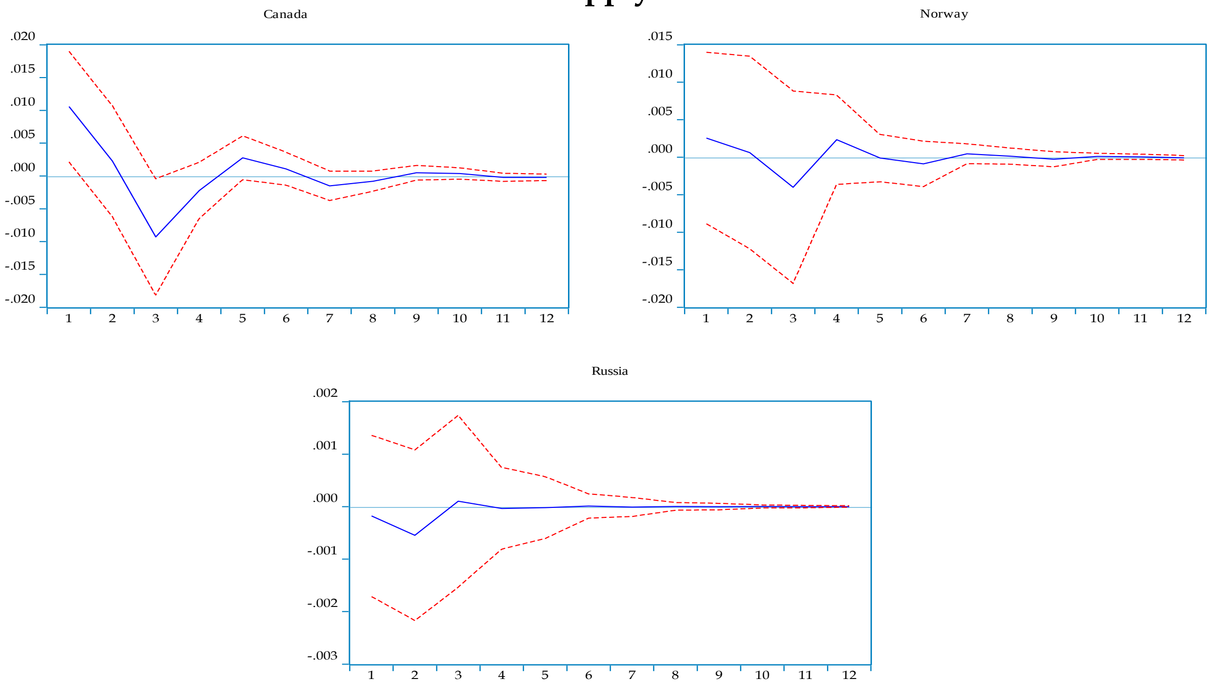


Figure 8: Impulse Responses of Selected Non-OPEC Members Oil Supply to Shocks in US Oil Shale Supply



The results presented in Table 2 show the historical decomposition of variance. Historically, both the US crude and oil shale supply shocks have made comparatively significant contributions to OPEC supply of crude oil. However, the contributions of US crude oil supply shocks to non-OPEC member states seem negligible compared to those of US oil shale production. Moreover, there is evidence of supply disruptions of crude oil for both OPEC and non-OPEC members in 2011. Owing to significant improvements in hydraulic fracturing that saw the drilling costs of oil shale to fall, the US shale production around 2010 turned from a marginal outlier in global oil production to a mainstream energy supplier. This recent trend in the US shale oil production may be partly responsible for its significant influence in the global crude oil market.

Table 2: Contribution of US Crude Oil Supply Variability to Shocks in OPEC and Non-OPEC Crude Oil Output

Horizon	2		3		6		9		12	
	Crude	Shale	Crude	Shale	Crude	Shale	Crude	Shale	Crude	Shale
Panel A: OPEC										
OPEC Total	0.4795	2.3084	1.0695	3.1098	1.1488	3.0515	1.1494	3.0503	1.1494	3.0502
Algeria	0.0018	0.0131	0.0037	0.0319	0.0694	0.0843	0.0702	0.0873	0.0702	0.0875
Angola	0.5305	0.2936	0.5095	0.3502	0.5923	0.4987	0.5925	0.4983	0.5925	0.4983
Ecuador	0.8559	0.1040	0.8424	0.3710	0.8653	0.3757	0.8654	0.3758	0.8654	0.3758
Gabon	0.4093	0.0310	0.4560	0.3391	0.8137	0.3809	0.8316	0.3820	0.8322	0.3813
Iran	0.2194	1.7679	2.4595	3.5677	2.6240	5.4437	2.6547	5.8219	2.6573	5.8843
Iraq	0.0015	1.5543	0.4298	1.4522	0.7212	1.4407	0.7256	1.4387	0.7257	1.4386
Kuwait	1.0560	0.3156	1.3299	1.3000	1.3614	1.5728	1.3622	1.5825	1.3622	1.5827
Libya	1.0596	0.4999	1.0287	0.5425	1.0311	0.5763	1.0319	0.5754	1.0319	0.5754
Nigeria	0.3295	0.0038	0.3812	0.0128	0.5257	0.0218	0.5327	0.0220	0.5328	0.0220
Qatar	0.3917	0.1648	0.3786	0.8128	0.7538	0.7944	0.7561	0.7930	0.7561	0.7930
Saudi Arabia	1.5493	0.3522	2.1458	1.4747	2.1303	1.6331	2.1305	1.6595	2.1305	1.6611
UAE	0.1805	0.0116	0.1817	0.4285	0.1901	0.4598	0.1902	0.4634	0.1902	0.4634
Venezuela	0.0002	3.8909	0.6965	6.6336	0.7022	6.6005	0.7025	6.5960	0.7025	6.5960
Panel B: Non-OPEC										
Non-OPEC	4.3089	1.3871	5.3692	3.0869	5.6376	3.1774	5.6478	3.1976	5.6479	3.1992
Canada	0.0936	0.2607	0.4135	1.4584	0.6963	1.5053	0.7536	1.5416	0.7558	1.5426
Norway	0.0151	1.5658	1.2769	3.2801	2.6905	3.7605	1.8048	3.7785	2.8116	3.7796
Russia	0.1637	0.0298	0.2408	0.0598	0.2467	0.0606	0.2467	0.0605	0.2467	0.0605

Note: Panel A and B shows the percentage contributions of US crude oil supply variability to structural shocks in OPEC and Non-OPEC crude oil supply for different horizons.

5.0 Some policy implications

The results presented in the last section reveal some discerning characteristics of major oil producers to the increasing supply of oil by the US, especially from unconventional sources. In this section, we review some policy implications of boom in shale oil production for selected OPEC and Non-OPEC oil giants.

Previous modelling results supported the view that OPEC responses to changes and shocks in the global oil market do not follow a competitive pattern. However, the addition of shale into the global oil commodity basket appears to pose a threat that is structurally different from the conventional oil as OPEC behavior in the presence of shale faces an "uncharted territory" (Fattouh and Sen, 2015). For example, conventional crude oil production projects usually last for about thirty years and are mainly financed through equity-financed investment mostly undertaken by multinational firms. Also, their capital and operational expenditure are structured such that they require high capital costs with relative low extraction costs. On the contrary, shale oil involves lower investment relative to conventional oil with higher production costs. The market is dominated by small firms, mostly independent US firms and its projects typically last one year or less. Also, its market is characterized by a high degree of financial leveraging (Ansari, 2017).

These diverse characteristics of the conventional oil which is the major source of exports and revenue for most OPEC countries and the unconventional shale oil have large implications for the demand and supply elasticity of oil. For instance, the export patterns of OPEC oil have experienced changing circumstances in the last decade. The lifting of the US crude oil export ban has allowed for the development of a new cross-trade and constrictions on the existing ones. Global oil inventories have been rapidly growing with global oil supply especially from non-OPEC countries, outpaced global oil demand.

There have been landmark decisions on production adjustments by OPEC and non-OPEC participating oil producing countries on the urgency to bring forward market rebalancing between the declining demand and excess supply. The "Declaration of Cooperation" focused on accelerating the drawdown of the global stock overhang in order to hasten the return to sustainable global oil market stability. However, oil dependent countries must individually address the challenges that accompanied the market imbalances.

In a bid to narrow deficits as a result of declining crude oil export revenue, Saudi Arabia and UAE have introduced value added tax, a pivotal measure to end tax-free living and boost non-oil income. Other oil giants may need to toll similar line towards boosting their non-oil revenue base to forestall the possibility of the impending market crisis.

6.0 Concluding remarks

The forecast that US will surpass Saudi Arabia and Russia in the coming years to become world's largest producer and exporter of oil, on the basis of potential shale oil boom, calls for concerns especially among conventional oil producing nations. Analysis and understanding of the market dynamics of US increased oil output on the supply of major oil supply – OPEC and selected non-OPEC member countries constitute the focal interest of this study. Starting with the prominent model of Killian (2009) on US response to shocks in global oil demand, we employ the SVAR model in an extended form to account for oil supply response by OPEC and non-OPEC countries to shocks as a result of US increased oil supply. Findings from the impulse responses show that oil exports, particularly for OPEC member countries, respond significantly to US oil supply shocks. The forecast error variance also shows that shocks from shale oil are more dominated by OPEC countries than their non-OPEC counterparts. However, in contrast to the dominance of shale oil shocks for OPEC, shocks from US crude oil supply are dominant among non-OPEC countries.

Our results' major implication is that oil dependent economies, especially those involved in conventional crude oil, need to recognise the changing nature of the global oil market and the possibility of US dominance in the market. Hence, key economic policies, particularly those geared towards alternative sources of financing government budgets and away from the almost total reliance on oil are inevitable.

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