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Oil Production in OPEC Countries: A Fractional Integration Study

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Abstract

This paper investigates the structure of oil production in the OPEC by using techniques based on fractional integration. This analysis permits us to determine if exogenous shocks affecting the series will have transitory or permanent effects. The results show evidence reversion to the mean (and thus transitory shocks) for Ecuador, Qatar, Algeria, Nigeria, Iraq and the U.A.E., and lack of it (and thus permanency of shocks) for Arabia Saudi and Angola. For the remaining five countries (Gabon, Kuwait, Iran, Libya and Venezuela) the results are ambiguous depending on the specification of the error term. Allowing for structural breaks, we notice that most of the countries display about four breaks and the orders of integration change substantially across the countries and the subsamples.

Keywords: oil production, OPEC countries, persistence, fractional integration

1. Introduction

Since the formation of OPEC, analysts have focused on the role and effectiveness of this organization in the world oil market. The inclusion of powerful actors such as the Soviet Union into the market in the late 1950s and the cartel's policies, common to the Seven Sisters oil companies after the World War II, created a surplus in the world oil market (Brémond et al., 2012; Nazari et al, 2018). Before the formation of OPEC, the Seven Sisters(note 1) controlled the upstream operations, downstream operations and oil supplies. OPEC have tried to manage oil exports and supplies through joint ownership with oil countries and to compete with oil countries with the lowest possible risk. Indeed, the emergence of OPEC was a reaction from major oil producing countries against the policies of multinational corporations (Fattouh and Mahadeva, 2013; Wood et al, 2016; Noguera, 2017, etc.).

OPEC's objective is to co-ordinate and unify policies among its members, in order to secure fair (from the OPEC perspective) and stable prices for petroleum producers; an efficient, economic and regular supply of petroleum to consuming nations; and a fair return on capital to those investing in the industry. With its large reserves and exports, OPEC plays a central role in the crude oil market.(note 2)

The main purpose of this organization is to coordinate and integrate the oil policies of the member countries, designing methods to ensure the stability of the price of oil for oil producers, the efficient and affordable supply of oil to the consumer countries, a regular supply with fair and equitable returns for those who invest in the oil industry.(note 3) More than five decades have passed since OPEC's establishment and it has undergone many changes and developments during these five decades due to the changes in the global economy, political changes, and technological developments. During these five decades, many attempts have been made to explain OPEC's economic behavior and several models and patterns have been provided in this regard though there is no consensus regarding the behavior of OPEC (Nazari, et al, 2017, 2018).

Optimal decision-making to determine the oil production level for OPEC and member countries is very important. OPEC may make the best decision based on oil price predictions in order to increase production, while a wrong decision can cause a huge loss to the members. For example, decisions adopted to increase the production and supply of oil while buyers are faced with reduced requirements. This can lead to a sharp drop in prices, or lowering supply at an inappropriate time can result in less profit. In fact, the effect of production policies depends on the influence on OPEC of future market expectations and its long-term investment plans to increase the capacity of production (Fattouh, 2007; Lotfi & Navidi, 2014).

Over the past two decades, studies have been conducted on the existence of unit roots and/or fractionally integrated methods, and they may be divided into four categories. First, studies on energy consumption (Narayan and Smyth, 2007; Chen and Lee, 2007; Hsu et al, 2008; Lean and Smyth, 2009; Mishra et al, 2009; Gil-Alana et al, 2010; Narayan et al, 2010; Apergis and Payne, 2010; Hasanov and Telatar, 2011; Barros et al, 2012; Apergis and Tsoumas, 2012; Shahbaz et al, 2016); second, studies on energy production (Lean and Smyth, 2013; Narayan et al, 2008; Maslyuk and Smyth, 2009; Barros et al, 2011; Barros et al, 2016); third, studies on oil prices (Gil-Alana, 2001; Barros and Gil-Alana, 2011; Gil-Alana and Gupta, 2014; Gil-Alana et al, 2016; Monge et al, 2017); and fourth, studies which investigate the relationship between energy and other variables (Mahdavi-Adeli and Nazari, 2014; Banafea, 2014; Gil-Alana and Yaya, 2014; Cuestas and Gil-Alana, 2018), most of the studies are in this category.

In most studies in the field of energy economics, the researchers have employed nonstationarity tests to examine the null hypothesis based on the existence of a unit root. The nature as well as temporary and permanent effects of shocks, especially in OPEC countries whose economies depend on oil revenues, are important for policymakers. Also, to make shocks effective in the energy sector, especially crude oil, it is important to check if they are permanent or temporary. This paper investigates the statistical structure of the oil production behavior in OPEC countries by using fractional integration techniques.

The paper is structured in the following way: Section 2 details the methodology. Section 3 presents the data and shows the empirical results, while Section 4 provides the conclusions.

2. Methodology

The techniques employed in this paper are based on the concept of fractional integration, which belong to the category of long range dependence or long memory processes. We say that a process $(x_t, t = 0,1,2,\ldots)$ is d-integrated and denoted as $x_t \approx I(d)$, if it can be expressed as:

$$(1 - B)^d x_t = u_t, \quad t = 0, \pm 1, \ldots, \tag{1}$$

where B is the backshift operator, i.e., $Bx_t = x_{t-1}$, and u_t is 0-integrated, i.e., I(0), implying that it is second order stationary, and with a spectral density function that is positive and bounded at all frequencies. Thus, u_t might be (weakly) autocorrelated, for example, of the $ARMA(p, q)$ form, i.e., $\varphi_p(B)x_t = \theta_q(B)\varepsilon_t$, and in such a case, x_t is said to be a fractionally integrated $ARMA$, i.e., $ARFIMA(p, d, q)$ process.

In the empirical application conducted in the following section, x_t can be the errors in a model of the form,

$$y_t = \beta_0 + \beta_1 t + x_t, \quad t = 1,2,\ldots, \tag{2}$$

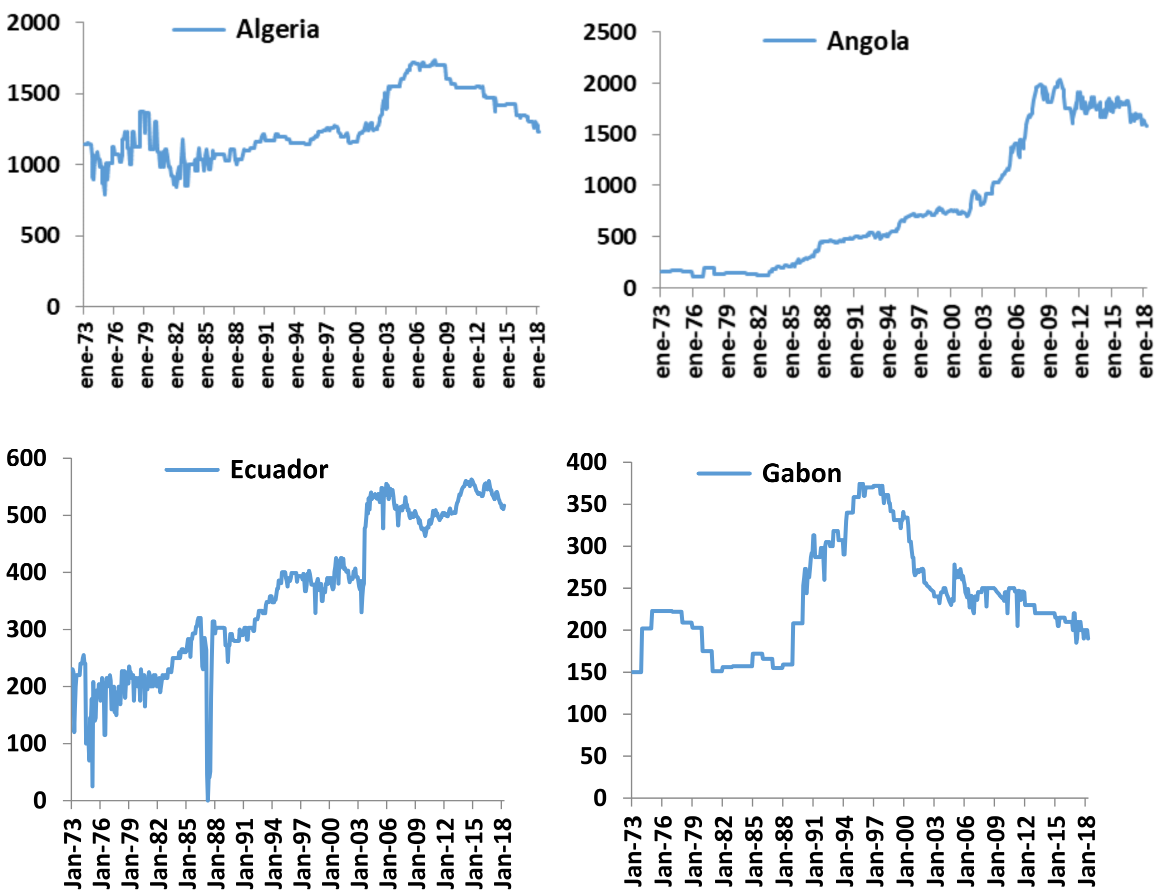
where β_0 and β_1 are coefficients corresponding to a constant and a time trend respectively.

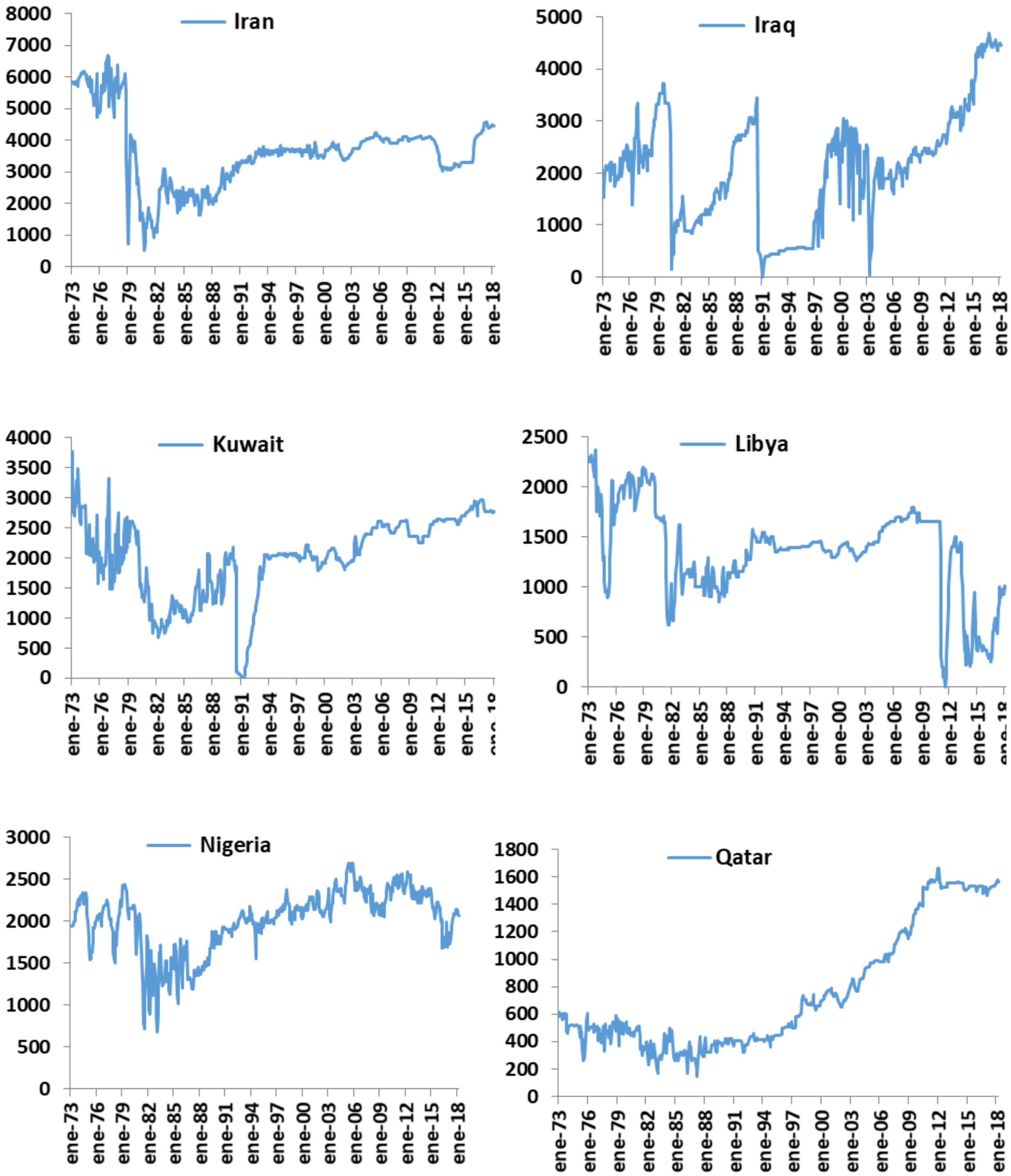
We estimate d along with the remaining parameters in the model by using the Whittle function, expressed in the frequency domain as in Dahlhaus (1989) and for this purpose we employ a parametric approach developed by Robinson (1994). This method is relevant in our context of potential nonstationary series, given that it remains valid for any real value of d, including values in the nonstationary range (that is, with d ≥ 0.5). Note that the estimation of d is crucial in the sense that it is telling us if shocks affecting the series will have transitory or permanent effects depending on the specific value of d.

3. Data and Empirical Results

OPEC has 1218.8 billion barrels of proven crude oil reserves, which is 71.8% of the world's reserves. Non-OPEC total production is 4.777 billion barrels, equivalent to 28.2%of the world's total reserves (BP, 2018).

Monthly data of the oil production of OPEC were obtained from January 1973 to April 2018 from the Energy Information Administration website (EIA, 2018). The data are seasonally adjusted. The total number of observations is 544 for each country: Algeria, Angola, Gabon, Ecuador, Saudi Arabia, Iraq, Iran, Kuwait, Libya, Qatar, Nigeria, United Arab Emirates, and Venezuela and OPEC. Figure 1 displays country specific monthly data of the oil production from 1973 to 2018. As one can see oil production in Algeria, Angola, Qatar, Iraq, Nigeria, Saudi Arabia, Ecuador and the United Arab Emirates (U.A.E.) and OPEC show an increase while Iran, Libya, Kuwait, and Venezuela show a decrease relative to 1973.




Iran
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Iraq
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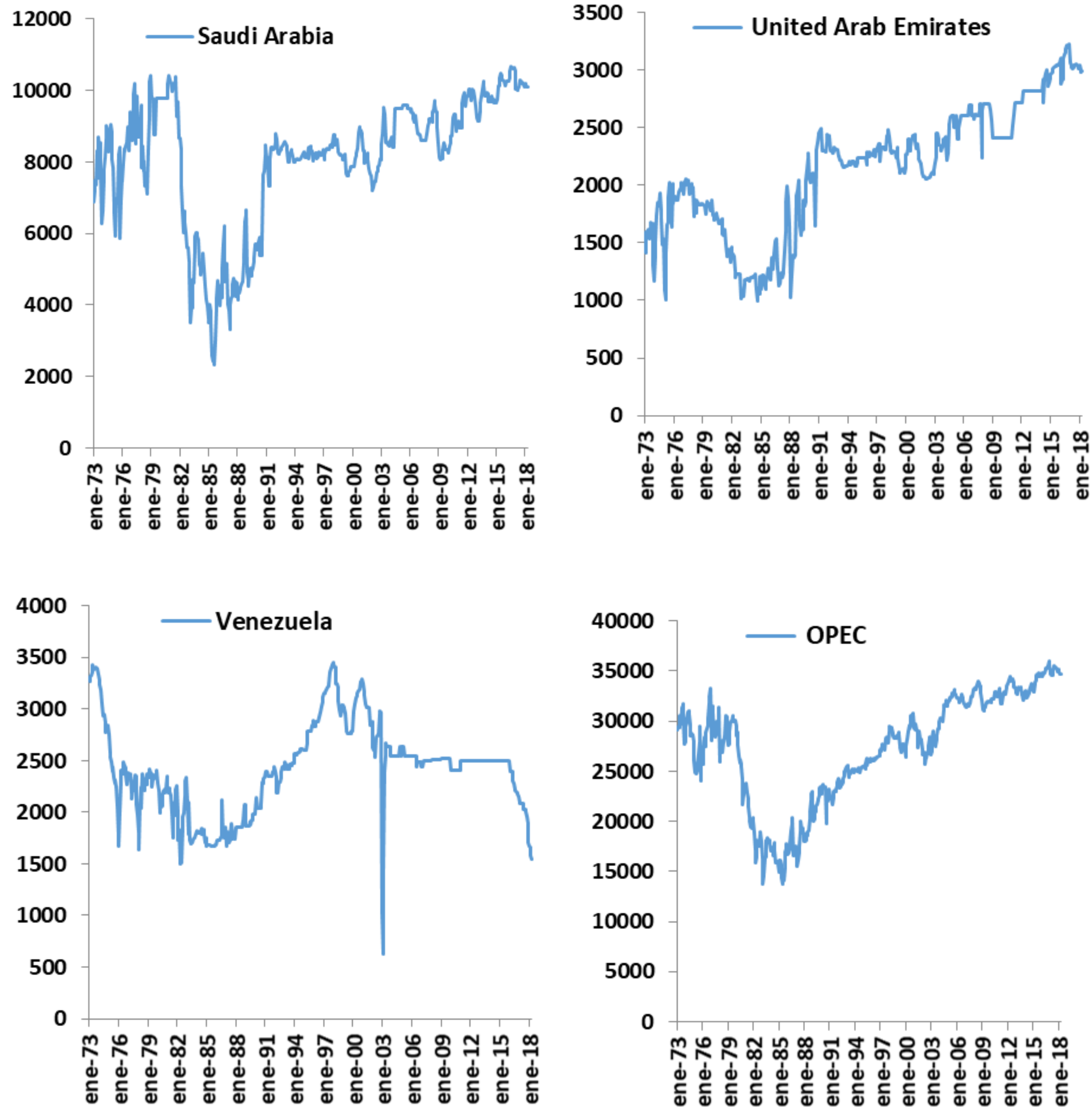

Figure 1. Time Series Plots: Oil Production

We observe in all series a strong persistent pattern that is changing across time, suggesting the adoption of fractional integration with and without breaks.

The model examined is the one given by equations (1) and (2), and we report in the tables the estimates of d along with the 95% confidence bands of the values of d where such hypothesis cannot be rejected using Robinson (1994) for the two cases of uncorrelated and autocorrelated errors. For the case of autocorrelation we use a method that is based on Bloomfield (1973). It is non-parametric because u_t in (1) is not fully parameterized but presented in terms of its spectral density function:

$$f(\lambda;\tau) = \frac{\sigma^2}{2\pi}\exp\left(2\sum_{r=1}^{m}\tau_r\cos(\lambda r)\right) \quad (3)$$

where σ^2 is the variance of the error term and m is a finite integer value. Bloomfield (1973) demonstrated that this function approximates well the behaviour of autoregressive (AR) models, and this function also accommodates well in the context of fractional integration (Gil-Alana, 2004, 2008).

We report across the tables the estimates of d for the three standard cases of no regressors, with a constant, and with a constant and a linear time trend, and mark in bold in the tables the selected cases according to these deterministic terms.(note 4)

If we assume that the errors are white noise, in Table 1, we see that for the OPEC overall production, the time trend is not required, and a constant is sufficient to describe this part. The estimated value of d is 0.89, and the hypothesis of I(1) is rejected in favour of mean reversion, noting that confidence interval excludes the value of 1. If we focus on the individual countries, we observe that the time trend is now required in three countries: Angola, Ecuador and Qatar. With respect to the integration orders we see that the estimates of d are statistically smaller than 1 and thus showing reversion to the mean for Ecuador (0.77), Qatar (0.78), Kuwait (0.80), Algeria (0.84), Nigeria (0.86), Iraq and the U.A.E. (0.88) and Gabon (0.93). For another group of four countries, the I(1) null cannot be rejected: Saudi Arabia (0.93), Venezuela (0.94), Angola (0.96) and Iran (0.97). Finally, for Libya, the estimate of d is equal to 1.15 and d = 1 is rejected in favour of d > 1.

Table 1. Estimates of d. Part I: No Autocorrelation

	---		A constant		A time trend	
OPEC	0.97	(0.91, 1.03)	**0.89**	**(0.84, 0.96)**	0.89	(0.84, 0.96)
OPEC countries						
Algeria	0.91	(0.85, 0.98)	**0.84**	**(0.78, 0.91)**	0.84	(0.78, 0.91)
Angola	0.95	(0.90, 1.00)	0.96	(0.92, 1.01)	**0.96**	**(0.91, 1.01)**
Ecuador	0.78	(0.72, 0.86)	0.77	(0.71, 0.85)	**0.77**	**(0.70, 0.85)**
Gabon	0.95	(0.90, 1.00)	**0.93**	**(0.89, 0.98)**	0.93	(0.89, 0.98)
Iran	0.99	(0.92, 1.06)	**0.97**	**(0.89, 1.06)**	0.97	(0.89, 1.06)
Iraq	0.90	(0.84, 0.98)	**0.88**	**(0.82, 0.96)**	0.88	(0.82, 0.96)
Kuwait	0.81	(0.76, 0.87)	**0.80**	**(0.75, 0.86)**	0.80	(0.75, 0.86)
Libya	1.07	(1.00, 1.15)	**1.15**	**(1.07, 1.25)**	1.15	(1.07, 1.25)
Nigeria	0.93	(0.86, 1.00)	**0.86**	**(0.78, 0.96)**	0.86	(0.78, 0.96)
Qatar	0.82	(0.78, 0.88)	0.79	(0.76, 0.83)	**0.78**	**(0.74, 0.82)**
Saudi Arabia	0.98	(0.92, 1.05)	**0.93**	**(0.87, 1.01)**	0.93	(0.87, 1.01)
U. A. E.	0.95	(0.88, 1.03)	**0.88**	**(0.81, 0.97)**	0.88	(0.81, 0.97)
Venezuela	0.95	(0.88, 1.04)	**0.94**	**(0.85, 1.06)**	0.95	(0.85, 1.06)

Selected model specification for each series are in bold.

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In parenthesis we refer to the non-rejection values of d at the 5% level.

Table 2 displays the results with autocorrelation. The structure is the same as in Table 1. For the OPEC, the estimated d is slightly smaller than in the white noise case (d = 0.87) but once more mean reversion takes place in this series. Focusing now on the individual countries, there are four countries with significant time trends: Ecuador, Qatar, the U.A.E. and Venezuela, and reversion to the mean is found in the cases of Venezuela and Nigeria (0.63), Ecuador (0.72), the U.A.E. (0.74), Iran (0.76), Algeria (0.79), Libya (0.84) and Qatar (0.85), while d = 1 cannot be rejected in the cases of Saudi Arabia (0.89), Kuwait (0.91), Gabon (0.97), and Angola (1.01).

Table 2. Estimates of d under the Assumption of Autocorrelation

	---		A constant		A time trend	
OPEC	0.94	(0.86, 1.06)	**0.87**	**(0.81, 0.96)**	0.87	(0.81, 0.96)
OPEC countries						
Algeria	0.84	(0.76, 0.96)	**0.79**	**(0.72, 0.87)**	0.79	(0.71, 0.87)
Angola	1.05	(0.96, 1.15)	**1.08**	**(1.00, 1.18)**	1.08	(1.00, 1.18)
Ecuador	0.72	(0.58, 0.87)	0.76	(0.67, 0.91)	**0.72**	**(0.59, 0.91)**
Gabon	0.99	(0.92, 1.06)	**0.97**	**(0.91, 1.04)**	0.97	(0.91, 1.04)
Iran	0.88	(0.80, 0.98)	**0.76**	**(0.69, 0.87)**	0.77	(0.70, 0.87)
Iraq	0.79	(0.71, 0.89)	**0.76**	**(0.68, 0.86)**	0.77	(0.67, 0.86)
Kuwait	0.84	(0.75, 0.96)	**0.91**	**(0.81, 1.03)**	0.91	(0.81, 1.03)
Libya	0.92	(0.82, 1.06)	**0.84**	**(0.73, 0.98)**	0.84	(0.73, 0.98)
Nigeria	0.79	(0.71, 0.90)	**0.63**	**(0.56, 0.74)**	0.63	(0.55, 0.74)
Qatar	0.87	(0.79, 0.96)	0.87	(0.82, 0.93)	**0.85**	**(0.80, 0.92)**
Saudi Arabia	0.95	(0.86, 1.06)	**0.89**	**(0.80, 1.01)**	0.89	(0.80, 1.01)
U. A. E.	0.83	(0.74, 0.93)	0.75	(0.67, 0.86)	**0.74**	**(0.66, 0.86)**
Venezuela	0.74	(0.65, 0.85)	0.61	(0.54, 0.69)	**0.63**	**(0.57, 0.71)**

Selected model specification for each series are in bold.

In parenthesis we refer to the non-rejection values of d at the 5% level.

Table 3 summarizes the results in terms of the estimated values of d. We see that for Ecuador, Qatar, Algeria, Nigeria, Iraq and the U.A.E., mean reversion is obtained in the two cases of uncorrelated and autocorrelated errors. On the other extreme, for Saudi Arabia and Angola, lack of mean reversion is found in the two cases. For the remaining five countries the results are more ambiguous. Thus, for Gabon and Kuwait, reversion to the mean occurs under no autocorrelation but lack of it with autocorrelated errors, and the contrary happens for Iran, Libya and Venezuela, where mean reversion takes place under no autocorrelation.

Table 3. Summary of the Results based on Persistence

No autocorrelation		Autocorrelation (Bloomfield)	
Mean reversion	No mean reversion	Mean reversion	No mean reversion
Ecuador (0.77)	Saudi Arabia (0.93)	Venezuela (0.63)	Saudi Arabia (0.89)
Qatar (0.78)	Venezuela (0.94)	Nigeria (0.63)	Kuwait (0.91)
Kuwait (0.80)	Angola (0.96)	Ecuador (0.72)	Gabon (0.97)
Algeria (0.84)	Iran (0.97)	U.A.E. (0.74)	Angola (1.08)
Nigeria (0.86)	Libya (1.15)	Iran (0.76)	
Iraq (0.88)		Iraq (0.76)	
U.A.E. (0.88)		Algeria (0.79)	
Gabon (0.93)		Libya (0.84)	
		Qatar (0.85)	

Next, we take into account potential breaks in the data. This is an important issue, because many authors have argued that fractional integration may be an artificial artifact created by the existence of breaks which have not been considered. We use Bai and Perron (2003) and Gil-Alana (2008) methods and the results were almost identical in the two cases. Table 4 displays the break dates for each series. We see that all countries experienced at least three breaks.

Table 4. Estimates of Breaks Using Bai and Perron's (2003) Methodology

Series	N. of breaks	Break dates
Algeria	3	1980M04, 2003M03, 2010M01
Angola	4	1982M09, 1990M05, 2000M03, 2007M09
Ecuador	5	1979M11, 1986M08, 1994M09, 2003M09, 2010M10
Gabon	4	1980M01, 1990M01, 1997M12, 2007M05
Iran	3	1980M01, 1990M05, 2011M08
Iraq	4	1980M10, 1990M08, 1998M02, 2010M03
Kuwait	3	1986M02, 1990M08, 2003M12
Libya	4	1981M05, 1990M02, 2004M11, 2011M08
Nigeria	4	1981M04, 1989M04, 2003M09, 2010M08
Qatar	4	1981M06, 1994M11, 2001M09, 2010M01
Saudi Arabia	4	1982M03, 1990M09, 2003M02, 2011M06
U. A. E.	4	1981M05, 1989M09, 2001M05, 2008M11
Venezuela	4	1983M12, 1994M12, 2001M09, 2011M08

According to the results displayed in Table 4, it was found that Ecuador has the most number of breaks, as many as five structural breaks, Algeria, Iran, and Kuwait had the least structural breaks, as many as three. Other countries have experienced four structural breaks. The structural break dates in these countries are resulted from various facts, including: the 1979 Iranian revolution, the Iran-Iraq war in the 1980s, the American economic recession in the early 1980's, the first Persian Gulf War (Iraq's invasion of Kuwait), the South East Asian crisis in the 1990's, the attack on the World Bank Twin Towers on September 11, 2001, the oil sector strikes in Venezuela in 2003, the second Persian Gulf War (US military strike against Iraq) in 2003, the global financial crisis in 2007, the Arab Spring, the internal disputes, and the disputes in Libya in 2011, and the US sanctions against Iran (including oil and chemical industry) in 2011 and 2018.

Table 5. Estimates of d for Each Subsample

	i) No autocorrelation					
	1^{st} subs.	2^{nd} subs.	3^{rd} subs.	4^{th} subs.	5^{th} subs.	6^{th} subs.
Algeria	**0.79**	0.72	**1.03**	0.62	---	---
	(0.63, 1.03)	(0.63, 0,83)	**(0.93, 1.18)**	(0.52, 0.75)		
Angola	**0.80**	**0.83**	**0.97**	0.73	**0.77**	---
	(0.49, 1.19)	**(0.60, 1.08)**	**(0.77, 1.26)**	(0.53, 0.99)	**(0.49, 1.24)**	
Ecuador	0.42	0.44	**1.16**	0.56	0.62	**1.12**
	(0.29, 0.59)	(0.35, 0.56)	**(0.92, 1.45)**	(0.44, 0.72)	(0.51, 0.76)	**(0.99, 1.31)**
Gabon	**0.98**	**0.98**	0,72	**0.90**	0.30	---
	(0.86, 1.15)	**(0.87, 1.12)**	(0.55, 0,97)	**(0.80, 1.03)**	(0.19, 0.44)	
Iran	**0.95**	**0.88**	0.67	**1.30**	---	---
	(0.73, 1.27)	**(0.75, 1.06)**	(0.60, 0.76)	**(1.19, 1.46)**		
Iraq	0.64	**1.02**	**0.74**	0.66	0.74	---
	(0.49, 0.88)	**(0.88, 1.18)**	**(0.56, 1.04)**	(0.50, 0.87)	(0.63, 0.90)	
Kuwait	0.58	**0.78**	**1.24**	**0.94**	---	---
	(0.49, 0.70)	**(0.51, 1.22)**	**(1.14, 1.38)**	**(0.85, 1.05)**		
Libya	**1.01**	**1.12**	**1.03**	**1.22**	**1.24**	---
	(0.87, 1.21)	**(0.82, 1.46)**	**(0.92, 1.16)**	**(1.06, 1.46)**	**(1.09, 1.44)**	
Nigeria	**0.94**	0.72	0.61	0.77	0.70	---
	(0.81, 1.10)	(0.34, 1.21)	(0.47, 0.79)	(0.63, 0.96)	(0.58, 0.86)	
Qatar	0.37	0.55	**0.84**	**0.94**	**0.86**	---
	(0.25, 0.52)	(0.44, 0.70)	**(0.69, 1.05)**	**(0.79, 1.14)**	**(0.71, 1.06)**	
Saudi	0.71	**0.99**	**1.02**	**1.10**	**1.09**	---
Arabia	(0.58, 0.90)	**(0.85, 1.18)**	**(0.88, 1.20)**	**(0.92, 1.35)**	**(0.87, 1.38)**	
U. A. E.	**0.79**	**1.05**	0.70	0.58	**0.87**	---
	(0.62, 1.03)	**(0.83, 1.34)**	(0.57, 0.86)	(0.43, 0.80)	**(0.74, 1.02)**	
	0.92	0.69	**1.28**	**0.85**	**1.24**	
Venezuela	**(0.77, 1.12)**	(0.59, 0.81)	**(1.14, 1.47)**	**(0.49, 1.32)**	**(1.12, 1.37)**	---

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ii) Autocorrelation

	1st subs.	2nd subs.	3rd subs.	4th subs.	5th subs.	6th subs.
Algeria	0.45	0.59	**1.06**	**0.85**	---	---
	(0.15, 0.84)	(0.44, 0.79)	**(0.88, 1.30)**	**(0.62, 1.15)**		
Angola	**0.96**	**0.90**	**0.90**	**1.00**	0.72	---
	(0.81, 1.13)	**(0,78, 1.07)**	**(0.80, 1.04)**	**(0.85, 1.22)**	(0.61, 0.87)	
Ecuador	0.48	0.68	0.24	0.53	**0.96**	**0.95**
	(0.22, 0.90)	(0.52, 0.87)	(-0.17, 0.95)	(0.31, 0.80)	**(0.66, 1.31)**	**(0.78, 1.19)**
Gabon	**0.95**	**0.93**	0.32	**0.91**	0.22	---
	(0.76, 1.23)	**(0.75, 1.20)**	(0.05, 0.64)	**(0.74, 1.16)**	(0.06, 0.44)	
Iran	0.36	**0.68**	0.70	**1.43**	---	---
	(0.11, 0.77)	**(0.44, 1.01)**	(0.58, 0.89)	**(1.18, 1.91)**		
Iraq	0.36	**1.06**	0.04	0.32	**0.76**	---
	(0.12, 0.74)	**(0.75, 1.41)**	(-0.18, 0.30)	(0.17, 0.54)	**(0.50, 1.07)**	
Kuwait	0.68	-0.05	**1.12**	**1.06**	---	---
	(0.48, 0.91)	(-0.41, 0.57)	**(0.99, 1.27)**	**(0.85, 1.30)**		
Libya	**0.78**	0.12	**1.12**	**0.86**	**1.10**	---
	(0.50, 1.07)	(-0.12, 0.56)	**(0.86, 1.66)**	**(0.55, 1.19)**	**(0.79, 1.50)**	
Nigeria	**1.05**	-0.32	0.27	**0.68**	**0.78**	---
	(0.67, 1.53)	(-0.49,-0.05)	(0.11, 0.51)	**(0.45, 1.06)**	**(0.59, 1.12)**	
Qatar	0.37	0.32	**0.73**	**0.72**	0.71	---
	(0.15, 0.71)	(0.14, 0.58)	**(0.41, 1.14)**	**(0.31, 1.28)**	(0.41, 0.94)	
Saudi Arabia	0.48	**0.83**	**0.87**	**0.77**	**0.47**	---
	(0.10, 0.92)	**(0.64, 1.13)**	**(0.55, 1.28)**	**(0.49, 1.16)**	**(0.08, 1.03)**	
U. A. E.	0.52	0.44	0.55	0.41	**0.92**	---
	(0.36, 0.85)	(0.22, 0.84)	(0.30, 0.87)	(0.18, 0.78)	**(0.74, 1.22)**	
Venezuela	0.64	0.71	**1.20**	-0.42	**1.27**	---
	(0.46, 0.92)	(0.56, 0.91)	**(0.90, 1.60)**	(-0.68, -0.08)	**(1.10, 1.49)**	

Table 5 displays the estimates of d for each subsample in each country using both assumptions of white noise and autocorrelation. With no autocorrelation we observe many cases where the hypothesis of I(1) cannot be rejected. Mean reversion is found in some isolated subsamples in practically all countries with the exception of Libya where the I(1) hypothesis cannot be rejected in any subsample. On the other extreme, the strongest evidence of mean reversion takes place with Nigeria with values below 1 in practically all subsamples. Allowing for autocorrelation (Table 5, Panel ii), reversion to the mean occurs in the first subsamples in the cases of Algeria, Ecuador, Kuwait, Qatar, the U.A.E. and Venezuela, and also in the last subsample for Angola and Gabon.

4. Concluding Remarks

The structure of the oil production in the OPEC has been examined by means of the integration orders of the series corresponding to each country from a fractional viewpoint. This allows us to ascertain the degree of persistence of the data, and more importantly, if shocks affecting the series have a transitory or a permanent nature.

The first interesting result is the high degree of heterogeneity across countries. Thus, evidence of mean reversion and transitory shocks is observed in the cases of Ecuador, Qatar, Algeria, Nigeria, Iraq and the U.A.E., while lack of it is obtained for Arabia Saudi and Angola. For the remaining five countries the results are inconclusive. Structural breaks are also examined. Most countries display four break dates and the orders of integration also change substantially across the countries and the subsamples.

The results of this paper show that crude oil production does not have a unified effect in all countries. Therefore, as a general conclusion, it can be said that there is no harmony and unity, as a cartel, among OPEC members, and due to special circumstances caused by internal/external changes, each country may face certain structural fractures.

To stabilize crude oil production for any country that abides with OPEC's policies, stabilization policies are necessary. Besides, given that crude oil production in some countries is mean reverting, it can be concluded that OPEC is faced with inefficiencies in the market. Finally, future researchers are recommended to categorize the countries in homogeneous groups and study crude oil sustainability within these groups. More research is required in this context.

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Notes

Note 1. The Seven Sisters comprised Anglo-Iranian Oil Company, Standard Oil Company of California, Texaco, Standard Oil Company of New Jersey, Standard Oil Company of New York, Gulf Oil, Royal Dutch Shell. Before the 1973 oil crisis, the various companies of the Seven Sisters controlled approximately 85 percent of the global oil reserves.

Note 2. http://www.opec.org

Note 3. http://www.opec.org/opec_web/en/about_us/24.htm

Note 4. These deterministic terms were chosen based on the t-values of the coefficients of the d-differenced processes.

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