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## **An analysis of OPEC oil production reaction to non-OPEC oil supply**

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# **An analysis of OPEC oil production reaction to non-OPEC oil supply**

## **Abstract**

This paper examines the impact of non-OPEC oil supply on OPEC oil production level at different quantiles of the OPEC production empirical distribution. It employs the Quantile Autoregressive Distributed Lags (QARDL) model that allows to probe simultaneously short-term connections and long-run cointegrating relationships across a range of quantiles. The analysis is undertaken using monthly data from **January 1993 to March 2020**.

The main findings show that the influence of non-OPEC production on OPEC production is symmetric in the long-run but quantile-dependent in the short-run. In the short-run OPEC production decreases significantly following an increase of non-OPEC production. However, in the long run, the increase in non-OPEC production causes OPEC production to rise. Furthermore, the results show that oil prices increase OPEC production in the long- and short-run. The potential policy implications for OPEC and non-OPEC oil production are discussed.

**JEL classification :** G12, E31, E32, Q40

**Keywords:** OPEC production, non-OPEC production, oil price, quantiles

## **I. Introduction**

The fundamental drivers of oil price are supply and demand which in turn are largely dependent on two main factors. The first one is related to economic events. Indeed, several historical oil prices declines were driven by weakening global demand, for instance, following U.S. recessions (1990–91 and 2001); the Asian financial crisis (1997–98); and the global financial crisis (2008-09). The second one is linked to geopolitical events. The 1973 Arab oil embargo, the 1980 Iran-Iraq war, the 1990 gulf war, are some of the historical geopolitical developments that have significantly impacted oil prices. The recent collapse in WTI crude price that occurred in Spring 2020 is the cumulative result of economic and geopolitical events. Indeed, the COVID-19 pandemic has caused restriction and containment measures that cause a drop-in consumption and sudden slowdown in the global economy. Consequently, the plummeting global demand for oil led to a fracturing between the two largest oil exporters. Saudi Arabia and Russia failed to reach an agreement on production cuts that exacerbate the crisis (OPEC, 2020b). As a result, Saudi Arabia cuts the price of its oil and decides to increase its production, to force Russia to return to negotiating with them (OPEC, 2020a).

The latest oil crisis and since then shed light on the role played by the Organization of Petroleum Exporting Countries (OPEC) in oil markets. Indeed, OPEC member countries produce about 40% of the world's crude oil and their exports represent about 60% of the total petroleum traded internationally, according to the United States Energy Information Administration.<sup>1</sup> Because of this market share, OPEC actions have a huge influence on international oil prices depending upon how many barrels per day the group will sell on the world oil market. Kaufmann et al. (2004) and Kaufmann et al. (2008) explained that OPEC as

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<sup>1</sup> United States Energy Information Administration. “What drives crude oil prices: Supply OPEC”, <https://www.eia.gov/finance/markets/crudeoil/supply-opec.php>, Retrieved 05/31/ 2021.

an international oil-producing cartel plays a considerable role in determining global oil supplies that influence oil prices. Déés et al. (2007) and Frondel and Horvath (2019) investigated OPEC's influence on oil prices over the medium- and long-run. They found that the key decision variables are the OPEC production quota and the OPEC ability to add production capacity.

For many years, the consequences of OPEC decisions about the production level on oil prices have been of interest for policy makers, regulators and also academics. An important question is still up to date; it concerns the response of OPEC oil production to non-OPEC oil supply. Indeed, in contrast to OPEC oil production, which is subject to central coordination, non-OPEC producers are independent in their decisions about oil production. As a result, non-OPEC producers tend to produce at or near full capacity and so have little spare capacity<sup>2</sup>. If global demand for oil falls, non-OPEC suppliers will continue to produce at their maximum potential. In their attempt to defend a target price, OPEC members would call for production cuts. If global demand for oil increases, the coordination and cooperation between OPEC and non-OPEC, is required to ensure that the world's rising demand is met in a full, timely and stable manner. In this case, the OPEC should rise the supply. Furthermore, other things being equal, when non-OPEC members decrease their supply levels, the global supply drops leading to an upward pressure on prices. There are some theoretical arguments and descriptive historical accounts that support that OPEC utilizes production cuts to prevent declines in price while on the other hand offsets disruptions in the supply of oil and the rise in oil prices by increasing production (e.g. Alrousan *et al.*, 2018; Barros *et al.*, 2011; Golombek *et al.*, 2018; Ramcharran, 2001). Given this background, we examine the impact of the non-OPEC supply on the distribution of OPEC production over the last decades. The main novelty of this paper is the investigation of the long- and short-run associations between OPEC and

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<sup>2</sup> United States Energy Information Administration. "What drives crude oil prices: Supply Non-OPEC" <https://www.eia.gov/finance/markets/crudeoil/supply-nonopec.php>, Retrieved 05/31/ 2021.

non-OPEC production using the quantile analysis. The contribution to the literature is twofold. First, this is the first attempt, to the best of our knowledge, to examine the long- and short-run interactions between OPEC and non-OPEC oil production as a direct association using quantile analysis. The importance of quantiles resides in the type of behavior (offensive or defensive) that OPEC countries adopted according to their own level of production (left tail – low quantiles or right tail – high quantiles of production distribution). More specifically, we adopt the Quantile Autoregressive Distributed lags model of Cho *et al.* (2015), that is referred to as QARDL, which is an extension of the ARDL model to quantile setting. The QARDL can address both long- and short-run dynamics across a range of quantiles of the dependent variable distribution in a cointegration setting. Lahiani *et al.* (2017) and Lahiani (2018), among others, show that QARDL model has several advantages over other conventional approaches in terms of time series analysis. The QARDL model allows involved variables to be of different order of integration; e.g.  $I(0)$  and  $I(1)$ . Furthermore, it allows testing for symmetric and asymmetric long- and short-run effects among involved variables according to the position of the dependent variable within its own distribution (i.e., distributional (a)symmetry), where the estimated coefficients may depend on the location of the dependent variable within its conditional distribution. Our findings in this regard contribute to the literature on the OPEC production behavior. Second, the study period from 1993M1 to 2020M3 include global economic events such as the Asian financial crisis which occurred in 1997, mortgage crisis in 2007-2008 and the recent outbreak of COVID 19 and then allows a deep analysis of the relationship between OPEC and Non-OPEC productions aver time. Geroski *et al.* (1987), Griffin and Neilson (1994), Brémond *et al.* (2012) and Fattouh and Mahadeva (2013) argue that OPEC's behavior varies over time depending on economic, market, and geopolitical conditions. Ratti and Vespignani (2015) explain the behavior of the two types of producers (OPEC and Non-OPEC) has changed over time.

The rest of the paper is organized as follows. Section 2 presents the literature review. Section 3 describes the data and presents the econometric model. In section 4, we discuss the empirical findings. Finally, section 5 concludes and provides useful policy implications.

## 2. Brief literature review

Many researchers have studied OPEC's influence in the oil market. Fattouh (2007) argue that by changing production quotas, OPEC and its dominant player Saudi Arabia are bound to have an influence on oil prices. OPEC sets production quotas based on its assessment of the market's call on its supply. In a supply–demand framework, the oil price is determined by OPEC and non-OPEC supplies. Then, the OPEC production level is indirectly determined by non-OPEC production level. In the same line, Pierru et al. (2020) explain that although OPEC's attempt to identify and offset shocks has not been perfect, OPEC plays an important role to achieve a significant reduction in the volatility of the price of oil. Déés et al. (2007) explain that OPEC played the role of the marginal producer during the 1986Q3–2000Q3 period. Indeed, during this period, OPEC generally sets production to match the expected difference between world oil demand and non-OPEC oil supply, which is determined largely by non-OPEC capacity (as price takers, non-OPEC producers generally operate at or near capacity). The policy simulations reported by Déés et al. (2007) indicate that non-OPEC production is inelastic to changes in price and that OPEC decisions about production impact oil prices. Echoing this, Almutairi et al. (2021), in their theoretical framework, assume that shocks to global oil demand and non-OPEC supply influence the call on OPEC's production. Barros *et al.* (2011) explain that OPEC's oil production is determined by a myriad of factors notably the price of oil and market conditions, i.e. the global demand for oil along with the production associated with non-OPEC oil producers. OPEC would adjust production quotas to achieve a desired price target zone. However, OPEC's ability to influence price is dependent

on market participants' expectations in the futures market. Barros et al. (2011) report that by the early 1980s the non-OPEC countries created pressure on OPEC through their production increase, which was attributed to the new reserves' discoveries and advances in new technology. Behar and Ritz (2017) explain that OPEC's strategy is determined by changes in oil global demand and non-OPEC production. Moreover, Ratti and Vespignani (2015) find that non-OPEC production affected OPEC production during 1974–1996 but not through 1997–2012. In fact, Ramcharran (2001) advised OPEC members to be cautious when evaluating policies related to production cutbacks as this has led to an increase in non-OPEC market share from mid 1980s. In line with this, Golombek *et al.* (2018) show that OPEC's real production cost advantage has diminished over the years, where the gap between OPEC and non-OPEC is narrowing in terms of real cost, creating more pressures on OPEC's policies and production plans. However, the authors point out that the production levels from non-OPEC countries increased over the last two decades, forcing OPEC's market share to stay steady at 40% since 1992. This suggests that the production of non-OPEC countries might have affected the market power of OPEC, especially that UK, Norway, and Mexico became active in the oil market since the 1980s (Ramcharran, 2001). Along these lines, Alrousan *et al.* (2018) show that the effect of non-OPEC sources on global oil production strengthened over time. Razek and Michieka (2019) empirically examine OPEC's role in light of changes in the global oil market, and the increasing importance China's role as a significant export market that influences oil prices and non-OPEC producers as important players in oil market. They conclude that OPEC production is mainly determined by the rest of the world's demand, and then by the rest of non-OPEC production. Furthermore, at longer horizons, non-OPEC production significantly decrease in case of a positive shock to OPEC production. Very recently, Alonso-Alvarez et al. (2022) have explored strategic interplays among large oil producers for the determination of the oil price in global markets. They have used a



Vector Auto Regression (VAR) model to evaluate how OPEC responds to supply increases in non-OPEC countries. They conclude that OPEC could decide either to follow non-OPEC production (Market Share Targeting) or to counteract it in order to stabilize prices (Price Targeting).

### **3. Data and econometric model**

#### **3.1. Data**

We study the monthly OPEC and non-OPEC production of oil together with oil price for the sample period from January 1993 to March 2020.<sup>3</sup> The data are collected from the US Energy Information Administration (<https://www.eia.gov>). OPEC and non-OPEC production is expressed in 1000 barrel per day while oil price is expressed in USD.<sup>4</sup> Figure 1 plots the OPEC and non-OPEC production. The study period includes several economic and financial crises together with several episodes of geopolitical turmoil. OPEC production dynamics appear to reflect such global events as many decreases of OPEC production are recorded. In particular, Figure 1 indicates that OPEC production decreased in 1998-2000, 2001, 2006, 2009 (global financial crisis), 2011 and 2013. In contrast, non-OPEC production had been growing from 1993 to 2020, and hence seems less reflective of economic turbulences occurred during the study period.

It is clear that both OPEC and Non-OPEC production grew over 1993 to 1997. This could be explained by the growth in Asia over 1990 to 1997 that contributed to rise world oil consumption and then oil price (Ratti and Vespignani, 2015). The OPEC production declines between 1997 and 1998 due to the Asian financial crisis. This crisis led to a decline in oil prices that has engaged rather speedily a producers' response involving non-OPEC countries and especially OPEC countries. The increase in OPEC production from 1999 is justified by

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<sup>3</sup> The data sample period is selected according to data availability.

<sup>4</sup> We use West Texas Intermediate (WTI) as a measure of oil price, which was deflated by US consumer price index (CPI) to get real oil price.

the recovery from Asian Financial Crisis that resulted in an increase of world petroleum consumption growth. This trend is reversed between 2001 and 2003 due to the recession in the U.S. on this period. Market volatility increased in an unprecedented manner in early 2008, before the collapse of the global financial sector that led to economic recession. OPEC became prominent in supporting the oil sector, as part of global efforts to address the economic crisis. OPEC decreased production target from September 2008 to January 2009. The decline in oil production during spring 2020 is a direct result of drop in demand caused by the economic slowdown generated by Coronavirus pandemic and global storage filling. This propelled OPEC to resort the largest and longest voluntary production adjustments in the oil market's history.

**< Insert Figure 1 here >**

Furthermore, before introducing the employed methodology, it is essential to check the order of integration of system variables as the QARDL requires the variables to be  $I(1)$  at most. It is extremely important to apply the most appropriate unit root test according to the patterns observed in data series. Accordingly, we run the Zivot-Andrews (1992) unit root with one break in intercept and trend, and the Narayan-Popp (2010) GARCH-based unit root test with two breaks in level and slope while accounting for a trend in data series. Hansen (2001) points out that failing to detect breaks in data leads to wrong interpretation of time series models and inaccurate forecasts due to biased parameter estimates.

Results in Table 1 show that OPEC production, non-OPEC production and WTI are  $I(1)$  while their first differences are stationary according to the two unit root tests with breaks. The previous result sustains our choice of the QARDL model to investigate the interdependency between OPEC production and non-OPEC production.

**< Insert Table 1 here >**

Table 2 reports results of Granger causality test and correlation measure between OPEC and Non-OPEC oil supply. Results indicate a unidirectional causality from non-OPEC supply to OPEC production of oil, meaning that Non-OPEC oil production is insensitive to OPEC oil production. The correlation between OPEC and non-OPEC oil production is 0.871, which highlights that OPEC and non-OPEC oil productions are strongly associated and seem to move together in the long-run.

< Insert Table 2 here >

### 3.2. Empirical methodology

#### 3.2.1. Quantile causality

While the linear Granger causality test detected a univariate causality running from non-OPEC production to OPEC production, results of the linear test hides some disparities in the strength of causalities at different quantiles of the OPEC production distribution. To further investigate the causality both in the tails and in the center of the distribution we carry out the quantile causality test recently developed by Troster (2018).

More precisely, the quantile causality methodology tests the null of “non-OPEC production (WTI price) does not cause OPEC at the  $\tau$  –quantile”. The previous test fails to reject the null of non-causality if:

$$Q_{\tau}(OPEC_t | OPEC_{t-1}, \dots, OPEC_{t-p}, NOPEC_{t-1}, \dots, NOPEC_{t-p}) = Q_{\tau}(OPEC_t | OPEC_{t-1}, \dots, OPEC_{t-p})$$

while it concludes that non-OPEC production causes OPEC production if:

$$Q_{\tau}(OPEC_t | OPEC_{t-1}, \dots, OPEC_{t-p}, NOPEC_{t-1}, \dots, NOPEC_{t-p}) \neq Q_{\tau}(OPEC_t | OPEC_{t-1}, \dots, OPEC_{t-p})$$

In the previous test  $Q_{\tau}(OPEC_t | \cdot)$  is the  $\tau$  –quantile of  $OPEC_t$  production and  $0 < \tau < 1$ .

The above quantile causality test was used intensively in the recent literature for several purposes. For example, Shahzad et al. (2019) tested for causality in quantiles to investigate whether gold still act as a hedge against inflation. The authors find evidence of a Granger causality-in-mean from the CPI to gold in the middle quantiles in their sample countries that includes China, India, Japan, France, UK and USA. Rehman and Apergis (2019) employ the quantile causality in mean and in variance to determine the predictive power between cryptocurrencies and real time commodity futures. Their results reveal significant causality running from cryptocurrencies to commodity futures both in terms of mean and in volatility in the majority of the quantiles. Jena et al. (2019) estimate time-varying causalities-in-mean and-variance between spot and futures markets respectively for crude oil, natural gas, gold and silver, depending on the states of the markets as proxied by the quantiles of the dependent variable conditional distribution. Results highlight that the causality in returns is asymmetric and unidirectional from futures to spot market for all commodities. The causality-in-variance is bi-directional in the normal to bull markets except for natural gas where it is unidirectional from futures to spot only.

### 3.2.2. Quantile ARDL

To further investigate the long- and short-run relationships between OPEC and non-OPEC oil production we adopt the QARDL model of Cho *et al.* (2015). The linear ARDL model that takes into account the direction of the causality between OPEC and non-OPEC oil production reported in Table 1 has the following form:

$$OPEC_t = \alpha + \sum_{i=1}^p \gamma_i OPEC_{t-i} + \sum_{i=0}^q \varphi_i NOPEC_{t-i} + \sum_{i=0}^r \delta_i WTI_{t-i} + \varepsilon_t \quad (1)$$

where  $\varepsilon_t$  is the error term defined as  $OPEC_t - E(OPEC_t/F_{t-1})$ , with  $F_{t-1}$  being the smallest  $\sigma$ -field generated by  $\{NOPEC_t, WTI_t, OPEC_{t-1}, NOPEC_{t-1}, WTI_{t-1}, \dots\}$ , and  $p$ ,  $q$  and  $r$  are lag orders selected by the Schwarz Information Criterion (SIC). In Eq. (1)  $OPEC_t$  refers to the OPEC oil production,  $NOPEC_t$  indicates the non-OPEC oil production and  $WTI_t$  represents

the West Texas Intermediate crude oil prices. All the variables in model (1) are transformed into their logarithm form.

Extension of model in Eq. (1) to a quantile framework leads to the following QARDL( $p, q, r$ ) model (Cho et al., 2015):

$$Q_{OPEC_t} = \alpha(\tau) + \sum_{i=1}^p \gamma_i(\tau) OPEC_{t-i} + \sum_{i=0}^q \varphi_i(\tau) NOPEC_{t-i} + \sum_{i=0}^r \delta_i(\tau) WTI_{t-i} + \varepsilon_t(\tau) \quad (2)$$

where  $\varepsilon_t(\tau) = OPEC_t - Q_{OPEC_t}(\tau/F_{t-1})$  with  $Q_{OPEC_t}(\tau/F_{t-1})$  is the  $\tau^{\text{th}}$  quantile of  $OPEC_t$  conditional of the information set  $F_{t-1}$  defined above (Kim and White, 2003).

Model (2) is then reformulated to the following form:

$$Q_{\Delta OPEC_t} = \alpha(\tau) + \rho(\tau) OPEC_{t-1} + \phi_{NOPEC}(\tau) NOPEC_{t-1} + \phi_{WTI}(\tau) WTI_{t-1} + \sum_{i=1}^p \gamma_i(\tau) \Delta OPEC_{t-i} + \sum_{i=0}^q \varphi_i(\tau) \Delta NOPEC_{t-i} + \sum_{i=0}^r \delta_i(\tau) \Delta WTI_{t-i} + v_t(\tau) \quad (3)$$

To avoid any likelihood of serial correlation between  $v_t$  and either  $\Delta NOPEC_t$  or  $\Delta WTI_t$ , Cho *et al.* (2015) suggest to project  $v_t$  on  $\Delta NOPEC_t$  and  $\Delta WTI_t$  such as  $v_t = \theta_{NOPEC} \Delta NOPEC_t + \theta_{WTI} \Delta WTI_t + \epsilon_t$ .

Incorporating the previous projection into Eq. (3) leads to the following QARDL-ECM model represented as follows:

$$Q_{\Delta OPEC_t} = \alpha(\tau) + \rho(\tau) (OPEC_{t-1} - \beta_{NOPEC}(\tau) NOPEC_{t-1} - \beta_{WTI}(\tau) WTI_{t-1}) + \sum_{i=1}^p \gamma_i(\tau) \Delta OPEC_{t-i} + \sum_{i=0}^q \varphi_i(\tau) \Delta NOPEC_{t-i} + \sum_{i=0}^r \delta_i(\tau) \Delta WTI_{t-i} + \epsilon_t(\tau) \quad (4)$$

The model in Eq. (4) has the advantage of measuring the long- and short-run influence of non-OPEC oil supply on OPEC oil production while controlling for the effect of WTI prices, and to test for the distributional asymmetric influence of non-OPEC oil supply on OPEC oil production. In other words, relative to the linear ARDL model that models the average relationship between Non-OPEC supply and OPEC production, which might show up

insignificant due to some reasons such as occurrence of outliers for example, the QARDL model is more flexible in that it allows to detect how some percentiles of the OPEC production react more or less importantly to Non-OPEC supply. The latter reaction might be significant at some quantiles (levels) of the OPEC production and insignificant for others. Consequently, our framework could be of great help to determine a level of production allowing OPEC countries to be insensitive to Non-OPEC production. The respective long-run effects of Non-OPEC oil supply and WTI oil prices on OPEC oil production at the quantile  $\tau$  are measured by  $\beta_{NOPEC}(\tau) = -\frac{\phi_{NOPEC}(\tau)}{\rho(\tau)}$  and  $\beta_{WTI}(\tau) = -\frac{\phi_{WTI}(\tau)}{\rho(\tau)}$ , respectively.

Cumulative short-run impact of past OPEC oil production on current OPEC oil production is measured by  $\gamma^*(\tau) = \sum_{i=1}^p \gamma_i(\tau)$ , while the cumulative short-run impact of present and past levels of Non-OPEC oil supply and WTI prices on current OPEC oil production are assessed by  $\varphi^*(\tau) = \sum_{i=0}^q \varphi_i(\tau)$  and  $\delta^*(\tau) = \sum_{i=0}^r \delta_i(\tau)$ , respectively for any quantile  $\tau$ . The previous long-run and cumulative short-run coefficients are computed using the delta method. The ECM parameter  $\rho$  is required to be significant and negative for the validity of the ARDL modeling.

We then perform the Wald test to investigate the respective asymmetric impacts of Non-OPEC oil supply and WTI prices on OPEC oil production. The Wald statistic asymptotically follows a Chi-Squared distribution. More specifically, the Wald statistic tests the null of parameter constancy across quantiles i.e. symmetry. The Wald test is carried out for each of the long- and short-run parameters. For example, the asymmetric role of Non-OPEC oil supply on OPEC oil production is tested using the null hypothesis  $\beta_{NOPEC}(0.05) = \beta_{NOPEC}(0.10) = \beta_{NOPEC}(0.20) = \beta_{NOPEC}(0.30) = \beta_{NOPEC}(0.40) = \beta_{NOPEC}(0.50) = \beta_{NOPEC}(0.60) = \beta_{NOPEC}(0.70) = \beta_{NOPEC}(0.80) = \beta_{NOPEC}(0.90) = \beta_{NOPEC}(0.95)$ .

Rejection of the above null indicates that Non-OPEC oil supply exerts an asymmetric effect on OPEC oil production in the long-run. Similar hypotheses and decision rules apply for the

remaining parameters, i.e. speed of adjustment, long-run effect of WTI and respective short-run effects of OPEC oil production, Non-OPEC oil production and WTI on OPEC oil production.

Quantile regression models have been largely used in the literature given their many advantages. More broadly, they have been used in panel data setting as well as in time series framework. For example, Bilgili et al. (2022) investigated the nexus between access to electricity and Co2 damage in Asian countries through panel quantile regression estimations. Sharif et al. (2020) used the QARDL model to study the impact of renewable and non-renewable energy consumption on Turkey's ecological footprint.

#### **4. Results and interpretations**

To further investigate the causal effect of Non-OPEC on OPEC production we performed the quantile causality test described in section 3.2.1 above. Results reported in Table 3 highlight some differences in the intensity of causality across the quantiles of OPEC oil production distribution. In particular, Non-OPEC oil supply weakly causes OPEC oil production at the low quantiles (significant at the 10% level), intensifies at the medium quantiles (significant at the 1% level) to vanish at the two highest quantiles (insignificant).

**< Insert Table 3 here >**

Table 4 reports the linear ARDL estimation results. Findings show evidence of linear cointegration between OPEC oil production, Non-OPEC oil supply and WTI prices as the speed of adjustment parameter,  $\rho$ , is significantly negative meeting thus the cointegration requirements. Non-OPEC oil production and oil prices exert a positive long-run impact on OPEC oil production with a higher impact of Non-OPEC oil production (0.468 versus 0.051). In particular, a 1% increase of NOPEC oil production (WTI prices) leads OPEC production to increase by 0.468% (0.051%).

As regards the short-run past dynamics results show that past levels of OPEC production have a positive cumulative effect on current level of OPEC production. In particular, the six-period lagged OPEC production has a significant positive effect on its current level. Moreover, current and past levels of Non-OPEC production have a negative cumulative short-run impact on current level of OPEC production. As expected, current and past levels of WTI prices at different lags increase current OPEC production. This result confirms the one of Ratti and Vespignani (2015) as the current and past levels of WTI prices at different lags increase current OPEC production. The latter result may indicate that OPEC countries adjust their oil supply following an increase of non-OPEC oil supply in order to maintain the oil price at a reasonable level. In fact, an increase of non-OPEC oil supply reduces oil prices while a disruption of non-OPEC oil supply leads oil prices to increase.

**< Insert Table 4 here >**

Figure 2 depicts the parameter estimates of the QARDL model along with their 95% confidence intervals. These results show that the speed of adjustment parameter,  $\rho$ , is significant and negative at all quantiles but the lowest quantile 0.05 in which case it is negative but insignificant. The latter finding indicates that there is reversion to the long-run equilibrium relationship between OPEC production and non-OPEC production, while no mean reversion between the previous variables is recorded at the lowest quantile 0.05, indicating that OPEC production and non-OPEC production deviate from the long-run equilibrium. The results also reveal that the long-run parameter  $\beta_{NOPEC}$  is positive and significant at all quantiles except at the lowest quantile, indicating an upward trending long-run relationship between OPEC and non-OPEC oil production, but there is no long-run relationship between OPEC and non-OPEC production at the lowest quantile 0.05. the latter results could be explained the shorter investment cycles of unconventional production cycles. Similarly, WTI prices have a positive long-run impact on OPEC production meaning that



WTI prices increase OPEC production in the long-run. The latter influence is significant at low to medium quantiles (0.1 – 0.6) only. The latter result highlights that OPEC countries incorporate oil prices in their production function up to a level of production returns of 0.37%<sup>5</sup>, whereas oil price does not predict larger OPEC oil returns.

**< Insert Figure 2 here >**

Analysis of short-run estimation results show that six-period lagged OPEC oil returns exerts a significant positive effect on current OPEC oil returns at low to medium quantiles only. Results also show a negative and significant influence of non-OPEC oil returns at low and medium quantiles for the lags 5 and 7 while for lag 6 non-OPEC oil returns reduces OPEC oil returns at quantiles 0.3 and 0.6. It is worth noting that there is no contemporaneous short-run relationship between OPEC and non-OPEC oil returns. Additionally, in the short-run WTI returns do not impact current OPEC oil returns contemporaneously nor with one-period lag. However, it has a positive two-period lagged influence on OPEC oil returns at the high quantiles. Indeed, recent advances in technology have freed up previously inaccessible resources, reducing production costs and increasing the speed at which supply can be adjusted to changes in demand. Again, the previous findings highlight the importance of quantiles as several lessons can be learned. Indeed, in the short-run, Non-OPEC supply and oil returns have only lagged influence on current OPEC oil returns. Consequently, OPEC countries should incorporate this lagged impact of Non-OPEC and oil returns in their production function in order to project their future production. Additionally, Non-OPEC oil returns reduce OPEC oil returns in the short-run at different quantiles for different lags. In particular, for lags 5 and 7 Non-OPEC oil returns reduce OPEC oil returns if  $\Delta\text{OPEC}$  is lower than 0.69% and for lag 6 Non-OPEC oil returns decreases OPEC oil returns if  $\Delta\text{OPEC}$  is -0.33% or 0.37%.

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<sup>5</sup> 0.37% is the 0.6th percentile of the  $\Delta\text{OPEC}$  empirical distribution.

Overall, the OPEC production responds positively (negatively) to non-OPEC supply in the long-run (short-run) and positively to oil prices in the long- and short-run. The latter results could be explained by the fact that OPEC countries reduce their oil production in the short-run following an increase of non-OPEC supply to sustain the oil prices, however, in the long-run they adjust their oil production to ensure a high long-run equilibrium with non-OPEC supply regardless of oil prices for low production (0.05 quantile) and high production (0.7 quantile and more). In other words, the OPEC countries are concerned by sustaining oil prices in the short-run while maintaining a reasonable market share in the long-run. Ratti and Vespignani (2015) showed that OPEC's behavior has shifted from responding to Non-OPEC production between 1974 and 1996 to responding to higher oil prices between 1997 and 2012.

Results of the Wald test for distributional asymmetry, reported in Table 5, show that the test fails to reject the null of linearity (parameter constancy across quantiles) for the long-run impact of non-OPEC production on OPEC production. However, the Wald test rejects the null of parameter constancy across quantiles for  $\beta_{WTI}$  indicating a distributional asymmetric influence of WTI prices on OPEC production in the long-run. In the short-run, the Wald test rejects the null of parameter constancy for the impact of two-period and four-period lagged OPEC production on current OPEC production. Results of the Wald test also show that, although insignificant, the impact of contemporaneous non-OPEC production on OPEC production is asymmetric as the Wald test strongly rejects the null of linearity. The same conclusion applies for the contemporaneous impact of WTI prices on OPEC production.

In summary, there is an asymmetric effect of non-OPEC production on OPEC production in the short-run but not in the long-run. In contrast, asymmetric effects of WTI prices on OPEC production are recorded in both, the long- and short-run.

**< Insert Table 5 here >**

## **5. Conclusions and policy implications**

The main goal of this paper was to investigate the quantile interaction between OPEC and non-OPEC oil production, in both the short- and long-run, over the period 1993:1-2020:3. The paper employed the recently developed Quantile Autoregressive Distributed lags model of Cho *et al.* (2015), where to the best of our knowledge, this is the first attempt to examine the OPEC and non-OPEC oil production association using the quantile regression model to cointegration.

The key findings suggest that in the long run, the increase in non-OPEC production causes OPEC production to increase. The quantile findings show positive and significant long-run effect at all quantiles except the lowest quantile 0.05. Meanwhile, in the short-run, the increase in non-OPEC production causes OPEC production to decrease. Non-OPEC production reduces OPEC production in the short-run at different quantiles for different lags. Furthermore, findings also show that non-OPEC production exerts symmetric (asymmetric) impact on OPEC production in the long-run (short-run). Our results suggest that growth in OPEC oil production can be predicted by growth in non-OPEC oil production

To this end, a number of important policy implications would emerge from our findings. First, OPEC countries should incorporate the lagged effect of non-OPEC oil supply

in their production function in order to project their future production or discussing quotas among their members. However, OPEC needs to consider that the non-OPEC countries are subject to difficulties that are interconnected with the economic, political, and legislative constraints of oil production. As such, OPEC might consider the heterogeneity in decision making by the non-OPEC countries regarding their oil production plans. Second, as non-OPEC production has symmetric effect on OPEC oil production, OPEC members should consider different defensive plans when considering the world market share. On the other hand, it is important for OPEC members to be aware of the fact that many decisions regarding adjusting the quota production are specific to each country, and also depend on the operational capacity of each member, which in turn is affected by the standing capital structure it has. Third, the interaction between OPEC and the non-OPEC countries in both the long- and short-run requires both sides to consider the risks of oil disruption that could end up increasing the cost of production, where instability in one country of OPEC or non-OPEC might spread to neighboring countries, increasing the risk of oil production volatility. Fourth, OPEC needs to realize that in the last decade it is facing serious threat in terms of its market share. It has to design new strategies that diverge from just controlling the production levels, as lately such policy shows temporary effect, especially that the new advances in the technology adopted in oil extraction has, over time, reduced the operating costs substantially in many of non-OPEC countries. Fifth, our findings stress the need for continuous cooperation between OPEC and non-OPEC countries for the sake of the oil market stability and world growth continuity. Finally, our findings could be useful for OPEC's de facto leader Saudi Arabia, that in the meeting of OPEC in March 2021<sup>6</sup>, has publicly encouraged allied partners to remain "extremely cautious" on production policy, "warning the group against complacency as it seeks to ensure a full oil market recovery".

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<sup>6</sup> <https://www.cnbc.com/2021/03/04/opec-meeting-saudi-arabia-and-russia-to-review-production-policy.html>

Although our findings are interesting for policy makers and academicians, this study has two main limitations. First, the empirical model allowed to account for distributional asymmetry it ignored other forms of nonlinearity and asymmetry such as threshold nonlinearity. Second, this study omitted other determinants of OPEC production than non-OPEC production and WTI prices. As such, our study could be extended by incorporating threshold nonlinearity in the QARDL model on the one hand, and including control variables such as global oil demand.

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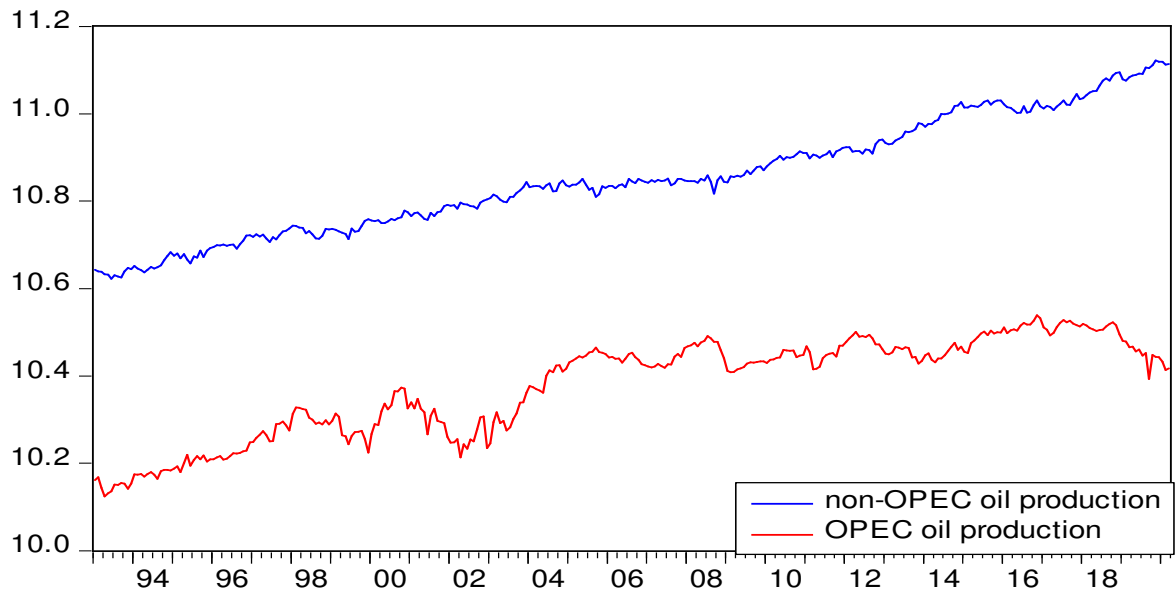
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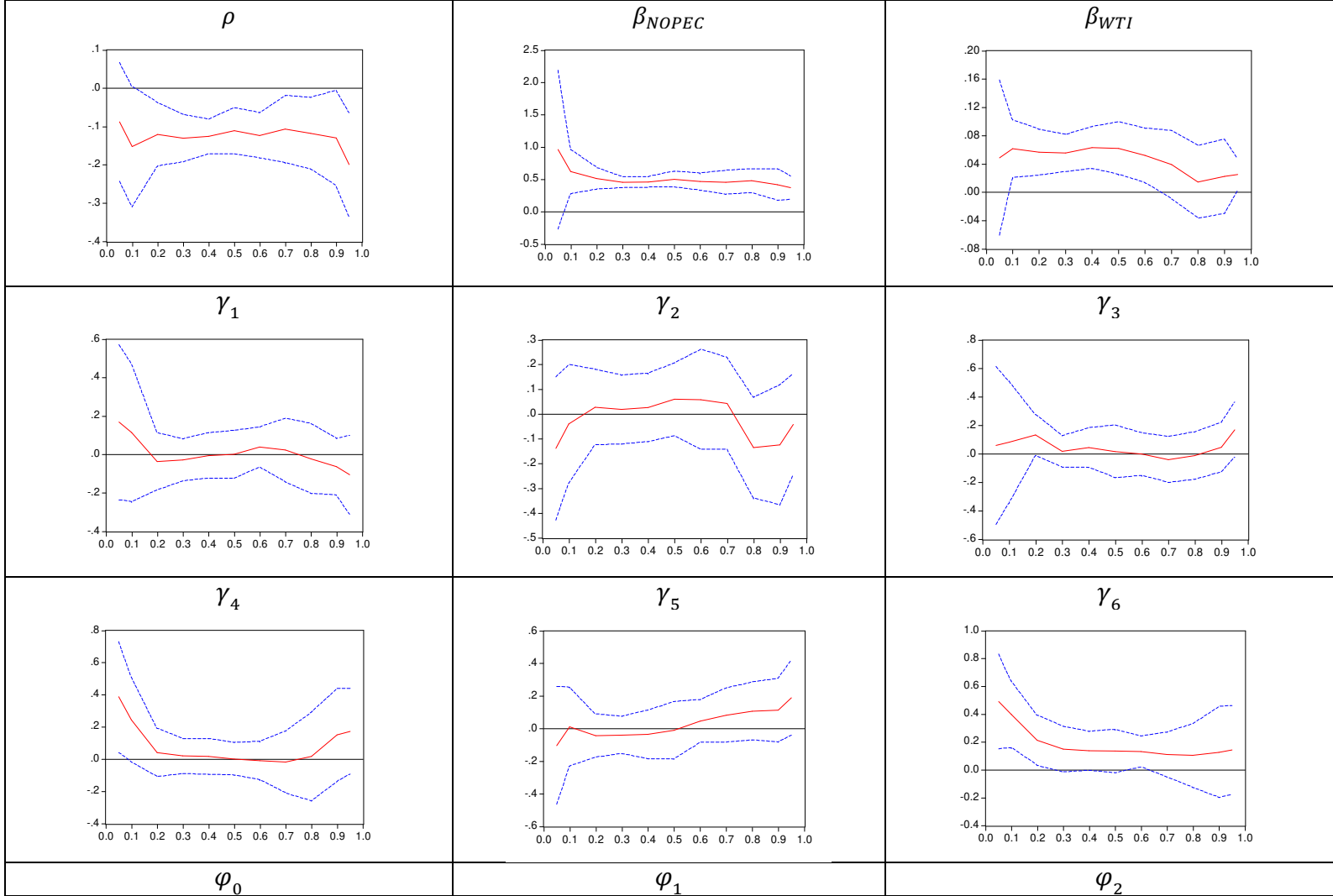


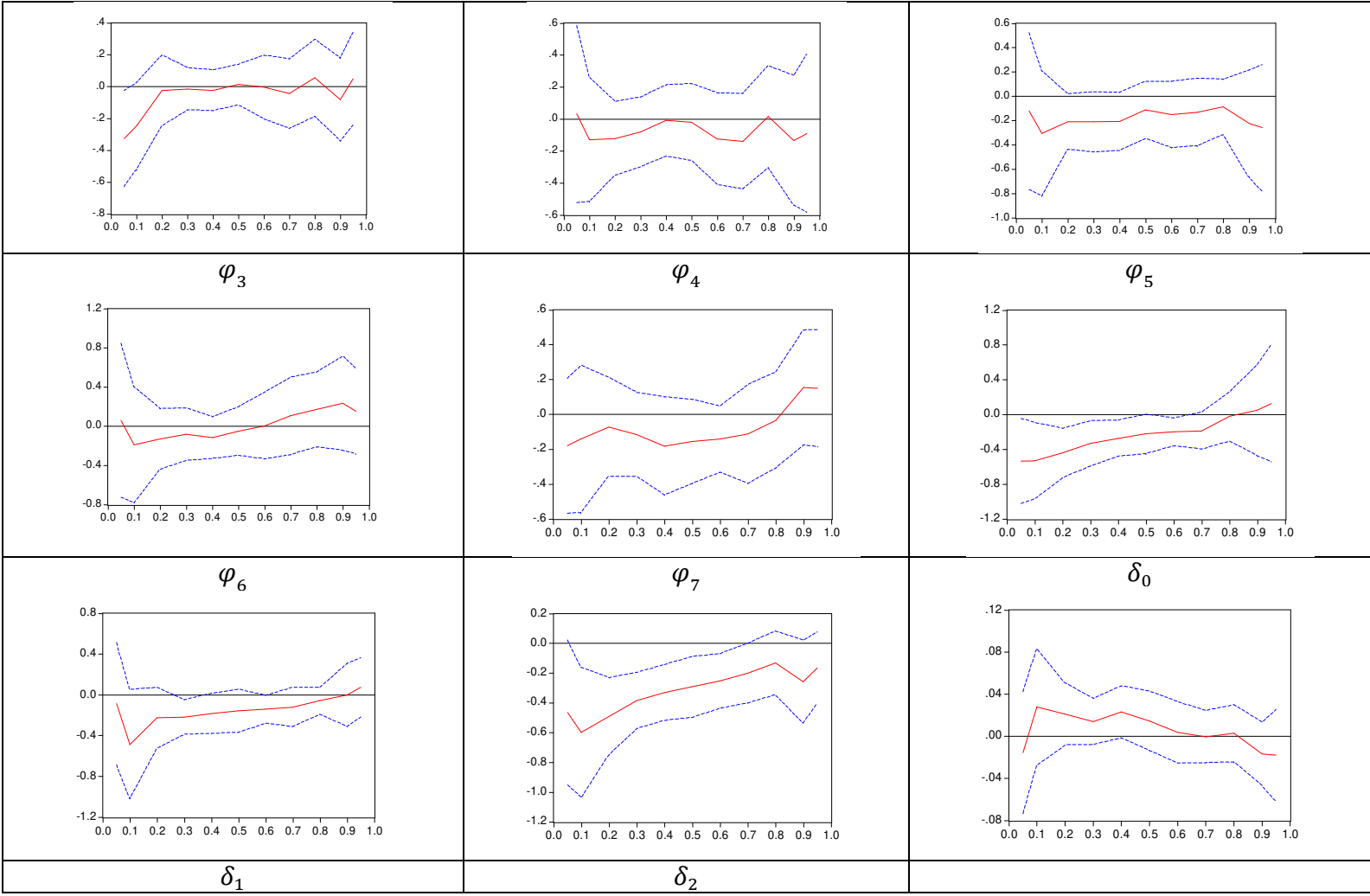
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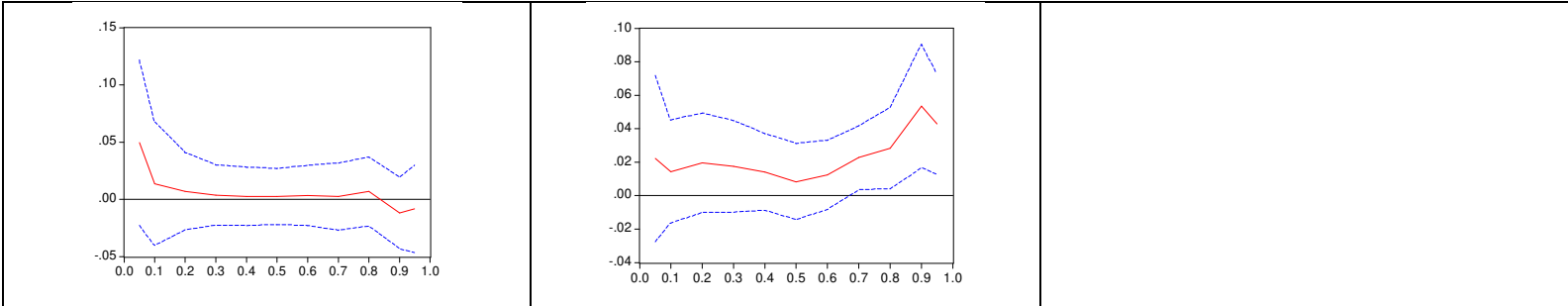
**Figure 1: OPEC vs. Non-OPEC production (1993:01-2020:03)**



**Figure 2: QARDL Parameter estimates**







**Note:** This figure depicts the quantile parameter estimates (red solid line) of the QARDL model along with their 95% confidence intervals, as represented by the dashed blue.

**Table 1: unit root test**

	ZA test		NP test	
	Level variables	$\Delta$ variables	Level variables	$\Delta$ variables
OPEC	-4.216	-16.990***	-4.386	-17.740***
NOPEC	-3.690	-16.768***	-2.928	-17.180***
WTI	-4.725	-11.399***	-2.764	-9.720***

Note: ZA denotes the Zivot and Andrews (1992) unit root test with one break in intercept and trend. Critical values for the ZA test are -5.570, -5.080 and -4.820 at the 1%, 5% and 10% levels, respectively. NP denotes the Narayan and Popp (2010) GARCH-based unit root test with two structural breaks in level and slope at unknown time. \*\*\*, \*\* and \* indicate the rejection of the null of unit root at the 1%, 5% and 10% levels, respectively.

**Table 2: Causality test & correlation**

<u>Panel A. Pairwise Granger Causality Test</u>		
Null Hypothesis:	F-Statistic	Prob.
NOPEC does not Granger Cause OPEC	4.523	0.012**
OPEC does not Granger Cause NOPEC	0.252	0.777

<u>Panel B. Correlation Coefficient</u>		
	OPEC production	Non-OPEC production
OPEC production	1	
Non-OPEC production	0.871	1

Note: This table reports the results of the Granger causality test (Panel A) and the correlation coefficient between OPEC and non-OPEC oil production (Panel B). \*\* indicates rejection of the null hypothesis of no causality at the 5% level.

**Table 3: Results of quantile causality test**

Quantile	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95
NOPEC	0.045	0.053	0.019	0.007	0.013	0.017	0.015	0.022	0.058	0.164	0.254
WTI	0.060	0.065	0.028	0.005	0.008	0.009	0.009	0.017	0.041	0.210	0.225

Notes: This table reports the p-values of the quantile causality test (Troster, 2018). The causing variables are non-OPEC production (NOPEC) and oil prices (WTI). The dependent variable is OPEC production (OPEC).

**Table 4: ARDL estimation results**

	<i>Coefficient</i>	<i>St. error</i>
$\rho$	-0.122***	-0.029
$\beta_{NOPEC}$	0.468***	-0.083
$\beta_{WTI}$	0.051***	-0.017
$\gamma_1$	0.021	-0.061
$\gamma_2$	-0.074	-0.06
$\gamma_3$	-0.018	-0.061
$\gamma_4$	0.093	-0.06
$\gamma_5$	0.007	-0.059
$\gamma_6$	0.203***	-0.059
$\varphi_0$	-0.078	-0.097
$\varphi_1$	-0.075	-0.11
$\varphi_2$	-0.219**	-0.112
$\varphi_3$	0.047	-0.111
$\varphi_4$	-0.098	-0.109
$\varphi_5$	-0.290***	-0.108
$\varphi_6$	-0.171	-0.107
$\varphi_7$	-0.349***	-0.099
$\delta_0$	0.001	-0.011
$\delta_1$	0.006	-0.012
$\delta_2$	0.029***	-0.011

Notes: This table reports estimation results of the linear ARDL model. \*\*\* and \*\* represent significance at the 1% and 5% levels, respectively

**Table 5: Results of the Wald test for asymmetry**

	<i>Coefficient</i>	<i>P-value</i>
$\rho$	1.420	0.169
$\beta_{NOPEC}$	3.390	0.971
$\beta_{WTI}$	16.440*	0.088
$\phi_1$	0.190	0.997
$\phi_2$	2.000**	0.034
$\phi_3$	0.670	0.749
$\phi_4$	2.890***	0.002
$\phi_5$	0.520	0.874
$\phi_6$	0.400	0.947
$\omega_0$	2.970***	0.001
$\omega_1$	1.060	0.392
$\omega_2$	0.760	0.665
$\omega_3$	1.570	0.116
$\omega_4$	0.560	0.846
$\omega_5$	1.060	0.392
$\omega_6$	1.010	0.438
$\omega_7$	1.490	0.143
$\theta_0$	3.540***	0.000
$\theta_1$	0.670	0.756
$\theta_2$	1.270	0.250

Notes: \*\*\*, \*\*, and \* represent significance at the 1%, 5%, and 10% levels, respectively.