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An Estimation of the Drivers Behind OPEC's Quota Decisions

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Key Points

This paper identifies key determinants that appear to shape OPEC's quota strategy and implementation. Using econometric estimations, it examines the factors that seem to most influence members' adherence to their production commitments in the short term and what drives the organization's quota decisions and level of compliance in the longer term. Key findings include the following:

- Global oil market indicators such as oil price, global crude oil demand, six-month global demand projections, and the output of non-OPEC producers primarily drive OPEC's quota decisions. Macroeconomic indicators, such as global gross domestic product growth and inflation, appear to play an insignificant role.

- The sampled OPEC member countries have different drivers of oil production. The output of the Gulf Cooperation Council countries and Iran is significantly affected by OPEC's quotas and their reaction to the compliance levels of other OPEC members.

- The national oil production of Algeria, Nigeria and Venezuela appears to be primarily driven by a portfolio of economic, financial and political indices.

- Exogenous shocks impact OPEC quota levels and production. These mostly include country-specific shocks which can be external (e.g., sanctions) or domestic (crises, strikes or military conflicts). The impact of such events, however, is usually alleviated on the OPEC level, indicating the organization's ability to balance its aggregate supply (Figure 1).

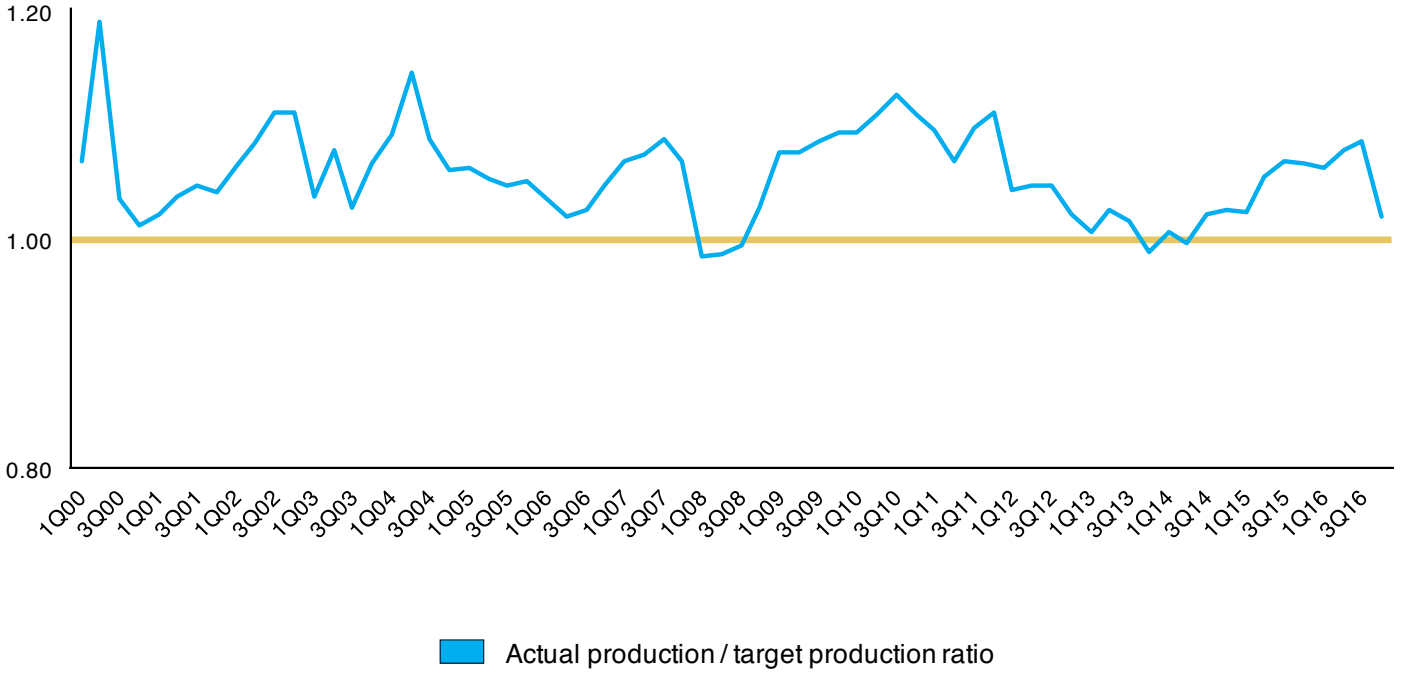

Figure 1. Average quarterly OPEC compliance level (actual output/production target).

Source: OPEC, KAPSARC calculations.

Key Points

In 2017, several non-OPEC members (Russia being the most significant) agreed to coordinate production cuts with OPEC to help re-balance the oil market. There have not yet been enough data on the impact of ‘OPEC+’ decision making; this study is therefore restricted to the period 2000 to 2016. In the future, with sufficient data to infer behavioral traits beyond the OPEC membership, we may be able to extend the analysis to include Russia.

Executive Summary

The factors OPEC takes into consideration when determining output quotas, according to their press releases, include a broad range of macroeconomic and global oil market indicators. Research suggests that the priority and importance of these indicators tend to shift over time. The heterogeneity of OPEC member countries and the inherent collective action problem further complicate the group's decision-making process and make forecasting OPEC's output problematic.

The output of OPEC members may significantly deviate from assigned targets, partially due to OPEC's organizational complexities. Such deviations are driven by each member country's ability and willingness to produce, which are, in turn, determined by economic, political and industry-specific drivers and can be impacted by a variety of external shocks. The year 2017 saw a strong compliance record from OPEC, although the question of whether such performance can be sustained in the long run remains unanswered.

This study examines the major drivers behind OPEC's decision making and the compliance of individual member countries. This helps facilitate an understanding of OPEC's reaction to shifts in the oil market, and to provide insights into the organization's strategies and production behavior of its member countries. For this purpose, it applies a structural time series model to quantify causal links between two groups of variables:

1) OPEC production targets (quotas) and macroeconomic/global oil industry indicators.

2) The actual output of selected OPEC member countries and country-specific economic, financial political and industry indicators.

This modeling approach also accounts for the impact of unobserved components: one-off events or structural breaks that such factors as extreme weather or infrastructure disruptions may induce.

The first part of the analysis aggregates quarterly OPEC oil production targets from 2000 until the end of 2016. It finds that OPEC's quarterly targets are driven by crude oil price dynamics and other global oil market indicators. Global macroeconomics seem to have no quantifiable impact on quota decisions. The paper identifies the following factors and their effect on OPEC's quota targets:

- The oil price (represented by the OPEC Reference Basket) has a positive effect. An increase in price is likely to lead to quota increases.
- Crude oil inventories have a strong negative effect in the short run, attenuated in the long run.
- Spare production capacity has a negative effect.
- Global crude oil demand has a positive effect.
- Six-months global demand projection has a positive effect.
- Output by non-OPEC producers has a positive effect in the short run and a slightly negative effect in the long run.

The second phase of the analysis estimates the actual output of each of the eight OPEC members, including Algeria, Iran, Kuwait, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela, using quarterly aggregation over the same time frame. This analysis introduces country-specific independent variables that represent their available spare production capacity and economic, financial and political contexts. Other variables – assigned quota and combined compliance of other members

– reflect individual member countries' responses to OPEC's group dynamics.

This analysis reveals that OPEC members cannot be treated as a homogenous group. They make production decisions for their own reasons. However, OPEC still plays a significant role in determining the oil production of its members, creating distinct intragroup interaction patterns.

The output of the Gulf Cooperation Council countries and Iran is largely driven by their OPEC membership, evidenced by the significant and positive impact of the assigned quota variable. These five countries also tend to demonstrate competitive behavior within the organization, as the combined compliance variable indicates: when all other member countries overproduce, these countries tend to follow suit. The output of Algeria, Nigeria and Venezuela is not driven by OPEC dynamics but by the impact of economic, financial and political factors.

Saudi Arabia stands out among its peers due to the relatively low impact of the combined compliance on its oil production, and the highest coefficient for spare capacity variables among the group. The data indicate that it is driven to a greater extent than its OPEC peers to stabilize the market – results indicate lower involvement in competitive behavior compared to other member countries – as Saudi Arabia's production trend runs counter to that of the group when acting as a 'swing producer.'

Saudi Arabia's production behavior helps attenuate the external shocks that affect the output of other OPEC members. These shocks are generally country-specific and tend to occur more often than those that impact OPEC as a whole. This study captured a number of such shocks for each of the analyzed countries during the period under consideration. They tend to fall into two groups. The first includes international events that impact the country's oil production, such as the imposition and subsequent relief of sanctions on Iran by the European Union, the United States and the United Nations. The second group comprises domestic economic and political factors. Increased government interference, political instability, national strikes and an economic crisis in Venezuela, for example, have had a detrimental effect on its oil production. Other members can also increase their production between the OPEC meetings in response to global supply disruption. As a result, external factors (those not captured by major decision variables) impact the quota targets on limited occasions. They can either be classified as disruptions to the global oil market or a combination of market trends that trigger a synergetic effect leading to an exaggerated market response, fueled by speculative behavior.

This study covers OPEC target oil production levels from 2000 until the end of 2016. It concludes that it will be difficult for OPEC to continue its 2017 compliance record, given the strong competitive behavior between its members, and the number of members whose output is primarily affected by domestic political and economic conditions. The successful continuation of OPEC production quota compliance also depends on any agreements reached with non-OPEC producers, a framework not observed in this study.

Introduction

OPEC accounts for over 40 percent of the global crude oil supply (OPEC 2017) and can exert significant influence on the market. In the short run, OPEC quota announcements and the expectations surrounding them impact the oil price and its volatility (Schmidbauer and Rosch 2012; Loutia et al. 2016). In the long run, the actual output levels of the member countries affect the global oil supply-demand balance, triggering shifts in spot and futures prices, inventory levels and instigating competitor responses.

OPEC's stated strategic objective is to stabilize oil markets and oil prices through coordinating its members' petroleum policies (OPEC 2012). The tactical considerations and drivers of its quota decisions appear to change, however, depending on market conditions and member countries' agendas. OPEC press releases refer to factors that it has taken into account when determining production quotas. These include stock levels (OPEC 2016), global economic growth (OPEC 2015), current and projected global oil demand, oil price dynamics (OPEC 2014), non-OPEC supply (OPEC 2013), and member countries' production capacity (OPEC 2005a) among other factors. OPEC's quota decision-making process is further complicated by discrepancies in agendas and the power balance of the member countries, arising from their varied production capabilities, economic and financial circumstances, and geopolitical ambitions.

Such complexity makes forecasting OPEC output difficult. Further complicating this task, the actual production levels of its members may significantly deviate from the established quotas. OPEC officials (OPEC 2005b; Korosec 2009) and market analysts (Faucon 2017; Voss and Dodge 2017) have identified compliance as one of the key issues facing the organization.

During quota setting negotiations, member countries usually arrive at a unified decision which might not account for all national interests and circumstances. The actual output, however, is determined by each country's ability and willingness to comply. In many instances, the assigned quota may be neither the only nor the most significant defining factor. Figure 1 shows the historical differences between agreed OPEC quotas and its actual output.

Analysts cite a variety of country-specific reasons for exceeding quotas. These include maintaining their balance of payment (Akacem and Fleisher 1994) and fiscal balance (Tagliabue 1986), compensating for the missed revenues in preceding periods (UPI 1983), and political reasons (MEPC 2015). Group dynamics can further exacerbate the issue. Member countries can also exceed assigned quotas because they feel the allocation is unfair (MENA 2003), or because other members are exceeding theirs (Fahey 2015). Some analysts see the OPEC quota enforcement challenge as the 'prisoner's dilemma' of behavioral economics, where actors choose not to cooperate despite their best interest in doing so (Seeking Alpha 2016; Chandler 2014).

The difficulties in estimating the output of OPEC member countries explains the large body of existing literature and applied methodologies on this subject. One strand of research studies the relationship between OPEC oil production on the organizational and country levels and its potential determinants, including the oil price (Kaufmann 2004), production levels of other members (Dibooglu 2006) and discovery rates (Ebrahimi and Ghasabani 2015). Another strand tries to estimate OPEC output using a set of explanatory variables. Matsumoto et al. (2012) define OPEC's crude oil production and export using resource limits, existing and projected demand, and peak points. Kaufmann et al. (2008)

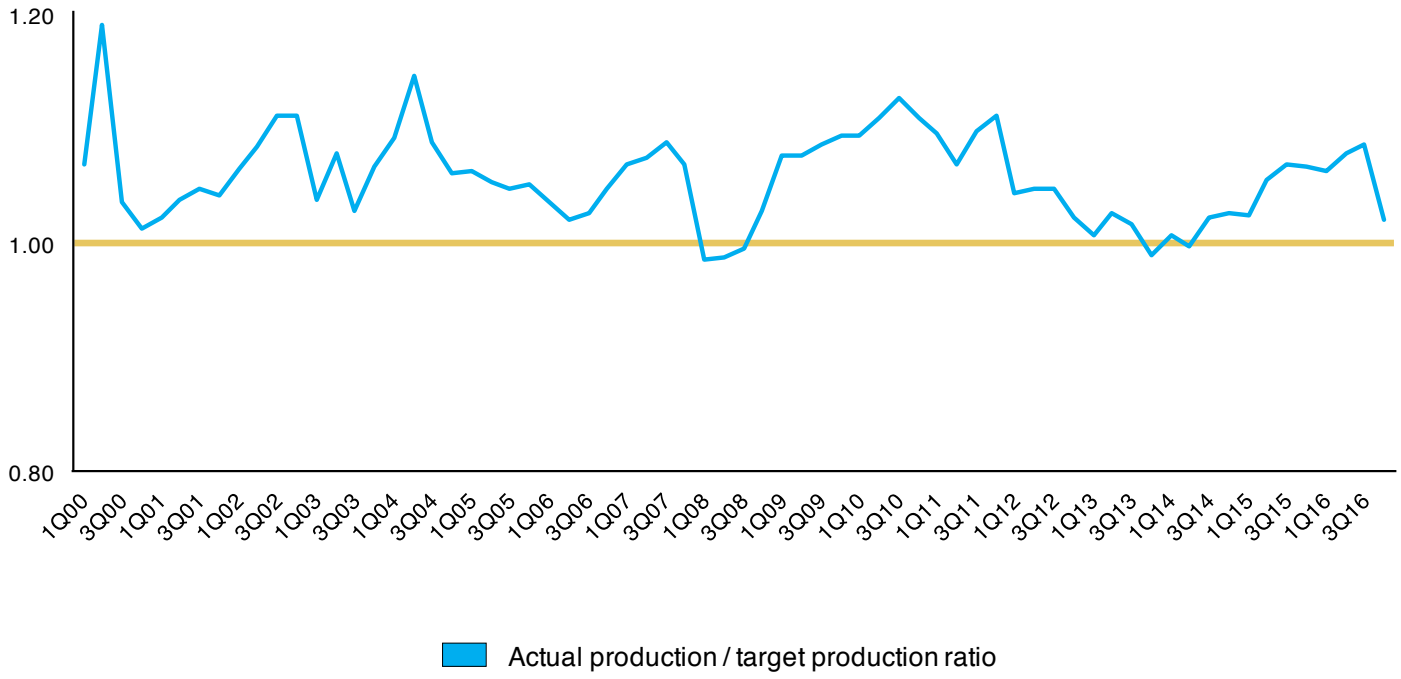

Figure 1. Average quarterly OPEC compliance level (actual output/production target).

Source: OPEC, KAPSARC calculations.

analyze the determinants of OPEC production by establishing a co-integration relationship between reserves, quota, prices and production capacity, and account for a set of political disruptions. Finally, some researchers have focused on OPEC group dynamics, exploring issues of coordination (Kisswani 2016), quota allocation (Gault et al. 1999) and bargaining process (Hyndman 2008).

The purpose of this research is to understand better and quantify the drivers of OPEC's quota agreements and the production levels of member countries. The proposed framework accounts for global oil industry indicators, individual countries' production capacities, economic, financial and political conditions, and intergroup dynamics (represented by compliance with assigned quotas). It deals with unobserved drivers such as behavioral trends (e.g., price speculation or geopolitical incentives) and technological shifts by creating a variable that aggregates these other factors. This analysis covers OPEC target oil production levels from 2000 until 2016. Production targets are aggregated for the whole organization and represented on a quarterly basis by taking an average number for each three-month period. The analysis tests the relationships between the dependent variable (quarterly OPEC production target) and its key determinants, using a structural time series model (STSM). Appendix A gives a detailed description of this method and approach.

Quota Decisions: It's Not Just About the Oil Price

The decision to abandon the target oil price band at the start of 2005 demonstrated OPEC's reassessment of its ability and willingness to unilaterally support price levels. Hence, the oil price is possibly no longer the only major factor in its quota decision-making process. In the communiqué from its 2005 meeting, OPEC refers to a number of market drivers that it considers when developing its quota strategy. These include current and projected oil demand, crude oil stocks, supply disruptions and geopolitical conditions (OPEC 2005c).

Table 1 presents significant variables that affect OPEC's quota decisions, contemporaneous and lagged (where applicable) coefficients and their statistical significance levels. All the variables in the preferred specification relate to global oil market dynamics.

The macroeconomic indicator – represented by the **global gross domestic product** (GDP) variable – proved to be insignificant. Appendix C details the output and diagnostics tests.

The **oil price** variable, represented by the OPEC Reference Basket price, remains a significant factor, although with a relatively small coefficient of 0.078. Its positive impact illustrates OPEC's strategy of market stabilization. When the commodity price

Table 1. Estimation results: OPEC quota decision variables.

Variables	Estimated coefficients	Variable definition
P_t	0.078***	Real price of OPEC basket crude oil
INV_t[1]	-1.037***	Combined global inventories of all crude oil grades
INV_t[1] – *lagged*	0.750***	
D_t	0.615**	Current world demand for crude oil
D_t – *lagged*	-	
$FUTD_t$	0.536**	OPEC six months projection of global oil demand
Y_t	-	Combined real global GDP
Y_t – *lagged*	-	
$SCAP_t$	-0.069***	Combined spare production capacity of OPEC members
$NOPROD_t$[1]	0.596*	Combined crude oil production of non-OPEC countries
$NOPROD_t$[1] – *lagged*	-0.659**	

[1] Long-run elasticites for applicable variables: INV_t (-0.287***); $NOPROD_t$ (-0.063*).
*, ** and *** denotes statistical significance at 10%, 5% and 1% respectively.

Source: KAPSARC research.

goes up, the organization is likely to increase its production quota to curb price speculation and reduce substitution behavior, while reaping the increased export revenues. This relationship also suggests that, despite its arguably diminishing market power, OPEC attempts to stabilize the global market in the bear cycles by reducing its planned output when the price plunges.

Elasticity coefficients indicate that the **crude oil inventories** variable is one of the major determinants of OPEC's production target, especially in the short run; its contemporaneous coefficient of -1.037 is the largest of the estimated parameters. Inventory levels are also widely regarded by market participants and researchers as a barometer of the current market status and potential short-run price changes (McCabe 2007; Bu 2014). The effect of crude oil inventories becomes somewhat attenuated in the long run, with the elasticity reduced to -0.287.

Spare production capacity appears to have a negative impact on OPEC's target setting level. The estimated elasticity of -0.069 is significant at the 1 percent level. This indicator is often viewed as a gauge for the future direction of oil prices (Cunningham 2016). When spare production capacity is reduced, buyers are induced to increase their stock levels. This can stimulate the spot oil price and drive the oil price in contango (Till 2015).

Global crude oil demand plays an important role in OPEC's target setting process, with an estimated elasticity of 0.615, significant at the 5 percent level. This result is also consistent with OPEC's strategy of supporting the market balance. It reflects the organization's willingness to cope with increasing demand from consumers and to promptly respond to sudden demand plunges, like the one that occurred during the recent crisis of 2008-2009. It should be noted that OPEC's strategy of adjusting its output targets to balance shifts in global demand is not only reactive. The positive 0.536 coefficient of the **six-month global demand projection** – also significant at the 5 percent level – suggests that OPEC relies on its demand forecast to anticipate market behavior and design appropriate responses.

Finally, the increase in **output by non-OPEC producers** seems to trigger an increase in output from OPEC in the short run. The contemporaneous elasticity is estimated at 0.596 with 10 percent significance. Contrary to the effect of the other variables within the market balancing strategy framework, this relationship exemplifies the organization's strategy of targeting market share. However, the long-term coefficient for non-OPEC output is slightly negative at -0.063, suggesting this strategy might be unsustainable in the long run.

These seven parameters provide a starting point for those interested in a broad understanding of OPEC's quota decisions. However, the actual determination of the OPEC output targets is complicated. This includes estimating a significant number of variables, and taking into account a mix of competing strategies (market balancing vs. capturing or retaining market share) and exogenous changes that can significantly impact the estimated outcome.

Production Drivers and the Various Approaches to Quota Compliance

This part of the analysis focuses on the drivers of crude oil output of individual OPEC member countries. It applies the same STSM method used for the quota estimations over the same time frame (quarterly figures from 2000 to 2016). The analysis omits Angola, Ecuador, Gabon, Iraq, Indonesia and Libya, as these countries were either not acting OPEC members for the entire period in focus or were engaged in conflicts. The analysis therefore focuses on the oil production drivers of Algeria, Iran, Kuwait, Nigeria, Qatar, Saudi Arabia, the UAE and Venezuela. Appendix A details the approach and model specification.

As discussed in the previous section, OPEC's actual output can deviate from the determined quota (Figure 1). Such deviation also significantly varies over different time periods. While the quota decisions are reached by consensus, actual output and, hence, compliance with allocated quotas are left to members' discretion. Moreover, OPEC has no formal mechanism for penalizing its members for quota violations (Sider and Faucon 2016). Therefore, it is more appropriate to use country-level indicators to analyze the drivers behind the organization's actual output levels.

This paper also hypothesizes that oil production by OPEC members is primarily driven by country-specific factors, such as production capacity, and economic, financial and political climates, rather than by the global oil market and global macroeconomic factors. Therefore, the STSM specification includes corresponding variables (see Appendix A for details). It also includes the **assigned quota** and **combined compliance of other OPEC members** variables to analyze countries' compliance behavior and intragroup dynamics. Table 2 shows the output according to this specification.

The pattern of significant variables and their elasticity coefficients across the sample countries indicates heterogeneity in OPEC members' oil production drivers. Except for the **spare capacity** variable, which appears significant for every country, there is a clear division between the members in the nature and degree of impact of their oil production determinants. These differences, in turn, translate into varying behaviors and strategies among OPEC member countries.

The most obvious distinction is between Algeria, Nigeria and Venezuela, and the GCC countries plus Iran. The first group seems almost unaffected by the allocated country quotas and the organizational dynamics (represented by their reaction to the compliance patterns of other members). The second group is broken down further based on the quota coefficients (higher impact for Saudi Arabia, Kuwait and Qatar) and the effect of socio-economic indicators. Oil production in Qatar and the UAE is positively correlated with the financial stability rating, while the output levels of Saudi Arabia and Kuwait seem to be primarily driven by policy decisions. Iran stands out from this group due to the effect of sanctions.

The estimation results suggest that OPEC still plays a significant role in determining its members' oil production, despite their demonstrated heterogeneity and history of compliance fluctuations. This is shown by the **production quota** variable, which is significant and positive for six out of eight sampled member countries.

Presumably, countries with the lowest compliance levels should have an insignificant **production quota** variable or associated low coefficients. This is indeed the case with Algeria, whose average deviation from the assigned quota

Table 2. Estimation results: variables defining OPEC members' actual output.

Variables	Estimated coefficients							
	Algeria	Iran	Saudi Arabia	Kuwait	Nigeria	Qatar	UAE	Venezuela
$QUOTA_t$	-	0.423***	0.632***	0.794***	-	0.703***	0.564***	0.064**
ER_t	0.094**	-	-	-	-	0.230**	-	-
ER_t – *lagged*	-	-	-	-	0.372***	-	-	-
ER_t – *long-run*[1]	0.094**	-	-	-	0.372***	0.230**	-	-
FR_t	-	-	-	-	0.261***	-	0.282***	0.110***
FR_t – *lagged*	-0.164**	-	-	-	-0.368***	0.238**	-	-
FR_t – *long-run*[1]	-0.164**	-	-	-	-0.107***	0.238**	0.282***	0.110***
PR_t	0.536**	-0.179*	-	-	-	-	-	-0.238***
PR_t – *lagged*	-	-	-	-	-	-	-0.336***	-0.091*
PR_t – *long-run*[1]	0.536**	-0.179*	-	-	-	-	-0.336***	-0.329*
$SCAP_t$	-0.002*	-	0.004***	-0.009***	-0.013***	-0.004***	-0.039***	-0.002***
$SCAP_t$ – *lagged*	-	-0.003***	-0.098***	-0.002**	-0.006***	-	-	-
$SCAP_t$ – *long-run*[1]	-0.002*	-0.003***	-0.094***	-0.011**	-0.019***	-0.004***	-0.039***	-0.002***
$OTHCOMP_t$	-0.130*	0.453***	-	0.374***	-	0.814***	0.340***	-
$OTHCOMP_t$ – *lagged*	-	0.236***	0.115*	-	-	-	-	-
OTHCOMP – *long-run*[1]	-0.130*	0.689***	0.115*	0.374***	-	0.814***	0.340***	-

[1] Long-run elasticities calculated from estimated coefficients.
*, ** and *** denotes statistical significance at 10%, 5% and 1% respectively.

Source: KAPSARC research.

during the observation period is the highest of the sample, at 113 percent. Its observed overproduction could be explained by the absence of the quota variable among the country's estimated production determinants. However, Nigeria and Venezuela, estimated to have a marginal or no quota effect, demonstrate average compliance rates of 103 and 98 percent respectively. This is closer to unity (100) than that of the GCC countries. Nigeria and Venezuela's average compliance rates are, however, heavily affected by their almost simultaneous slumps in production from 2012-2016. Meanwhile, overproduction by Kuwait and Qatar, countries with the highest quota coefficient that did not incur infrastructure or political disruptions, amounted to between 4-5 percent. This suggests that higher production elasticity with respect to quota indicates consistency in compliance rather than the level of compliance.

Saudi Arabia, which also managed to avoid major production disruptions, has a lower quota elasticity than its GCC peers (0.632). This may be due to its 'swing producer' behavior (Butler 2017; CFR 2016). Saudi Arabia possesses the largest volume of spare capacity in OPEC. This ensured its ability to ramp up production to make up for supply disruptions incurred by other OPEC members, thus causing it to exceed its quota.

Analysis of the **combined compliance of other OPEC members** variable also provides insights into

Overproduction and elasticity coefficients

No country whose production level is affected by the assigned quotas has an associated elasticity coefficient exceeding 1.0. Such elasticity levels can be deemed surprising (Kauffman et al. 2008), as coefficients north of 1.0 could be expected, given OPEC's history of quota overages. However, different scenarios can emerge when this relationship of overproduction and elasticity below 1.0 holds. For instance, if a country is already significantly exceeding its current limit, with a quota increase its output might grow by a smaller proportion to the permitted increase. Alternatively, when a country's quota is cut, it might not fully comply with its assigned reduction. Both of these scenarios result in overproduction with an elasticity coefficient below 1.0.

the organization's dynamics. Based on this criterion, the sample countries can be divided into three groups:

- OPEC members unaffected by the assigned quota: Algeria, Nigeria and Venezuela. These countries also seem to disregard other members' compliance in their production decisions.

- Countries which take assigned production quotas into account are engaged in intra-organizational competitive behavior, to varying degrees. The elasticities of the $OTHCOMP_t$ variable vary from 0.34 to 0.814 for Iran, Kuwait, Qatar and UAE, and imply that these particular countries tend to overproduce when OPEC as a whole produces more than agreed.

- The coefficient for Saudi Arabia is much smaller (0.115), though it is positive and statistically significant. This is explained by its 'swing producer' periods when its production trend opposes that of the group's. This type of behavior does not seem perennial, however, as the positive coefficient suggests a prevailing competitive behavior.

OPEC members demonstrated various production strategies in 2017. Saudi Arabia over-complied with its quota, compensating for overproduction from Iraq (not represented in this paper's sample), Iran and the UAE. The output of Iran and the UAE is to be expected given the coefficients for their production quota variable are among the lowest of the major Middle East producers (see Table 2). In the group unaffected by OPEC dynamics, Libya and Nigeria, which were not assigned production targets, had strong production recoveries. These recoveries offset the production difficulties faced by Venezuela and, to a lesser extent, by Angola.

Unlike the OPEC-related variables, the effect of which differs significantly across the sample countries, the **spare production capacity** is both statistically significant and has negative coefficients across the board. Saudi Arabia (-0.094), the UAE (-0.039) and Nigeria (-0.019) have the largest elasticities. These countries have the largest proportion of average spare capacity to average output. Available spare capacity allows them to ramp up production over the short and medium term, in contrast to more constrained

OPEC members such as Algeria with its elasticity of -0.002, Iran (-0.003) or Venezuela (-0.002).

These two groups of variables referring to OPEC membership and domestic production capacity can sufficiently determine the actual oil output of Saudi Arabia and Kuwait within the applied framework. The production levels of these countries seem to be unaffected by their economic, financial and political dynamics, in contrast to their peers. This might indicate that Saudi Arabia and Kuwait have been stable enough to avoid disruptions to their oil production, and/or their oil upstream sectors have been resilient to macroeconomic and political changes. Neither do Iran's economic financial indicators have a statistically significant impact on oil production. However, Iran appears to be affected by domestic political changes. The remaining countries, Qatar, the UAE, Algeria, Nigeria and Venezuela all seem to be affected by domestic economic and financial conditions.

The economic and financial indices applied in this analysis have a composite structure and comprise a number of indicators. These include GDP per capita, GDP growth, the proportion of GDP to budget balance and current account; inflation for the **economic index** and foreign debt as a percentage of GDP and exports, current account as a percentage of exports, net international liquidity and exchange rate stability for the **financial index**. See PRS (2017) for a detailed description and weights of particular components.

These indices can potentially affect OPEC members' oil production in two ways. Firstly, economic development and financial stability act as proxies for a country's investment potential and can support the development of the upstream oil sector. The link between OPEC countries' economic and financial development and crude oil output may be stronger than in regions dominated by international oil companies, given that national oil companies largely control OPEC oil production. However, a deteriorating financial and economic climate may also lead to increased oil production, even exceeding assigned quotas, to increase export and fiscal revenues and to improve current account balances.

The impact of the **economic rating** variable confirms the first scenario: economic and financial stability drive crude oil output. Algeria has a positive elasticity, with a coefficient of 0.094, similar to Nigeria (0.372) and Qatar (0.23). Qatar and the UAE have enjoyed explosive economic growth since the early 2000s, which has significantly improved their national financial indicators. There is also a positive effect of these countries' **financial rating** on their oil production, with respective coefficients of 0.238 and 0.282. Venezuela also has a positive link between its **financial rating** and oil production. Conversely, the negative elasticities of Algeria and Nigeria's financial rating suggest these countries tend to increase their oil revenues to alleviate budget and fiscal problems.

The **political rating** variable can have a positive effect on oil production, as in the case of Algeria with a 0.536 coefficient. Algeria started the observation period with the lowest **political rating** among OPEC members. Improvements in areas such as government stability, law enforcement, and external and internal conflicts have positively impacted its upstream industry development. The **political rating** variable can also have a negative effect, as political instability can induce governments to look for additional revenues to alleviate their fiscal problems. This trend is evident in the negative coefficients for Iran

(-0.179) and Venezuela (-0.329). The UAE does not fit exactly into either the positive or negative patterns associated with this variable. Its **political rating** index is the highest in OPEC, though it has deteriorated recently due to the country's increased engagement in Middle Eastern conflicts (BMI Research 2015). However, the UAE has expanded its oil production in recent years and has an ambitious plan to increase its output further (EIA 2015).

The Effects of External Shocks

Besides the effects of estimated variables described in the previous sections, both OPEC quota decisions and output of individual members are found to be impacted by exogenous factors. The identified stochastic underlying trend (UPT) captures such unobserved components and, in the first estimation of this study, is represented by the residual function of the various relationships impacting OPEC's production decisions. The estimated UPT function has a slightly downward trend, which reflects a decrease in OPEC's influence on the global oil market over the observation period and a necessity to self-impose lower output targets to achieve its desired market state.

Analyzing the underlying trend function allows for the isolation of specific interventions (see Appendix A for details). This study identified the following level interventions and corresponding time frames.

The level breaks presented in Table 3 are external, i.e., not captured by the independent variables, disruptions to the global oil market, or a combination of market trends and one-off occurrences that lead to exaggerated market responses and speculative behavior. This, in turn, prompts OPEC to respond, attempting to rebalance the market or retain its market share. The time stamps associated with the identified level breaks help identify those shocks:

2002 (Q1): The aftermath of the 9/11 attacks. There was no significant immediate impact on the oil demand, though crude oil inventories spiked and price dropped. The projections for the global economy and, hence, global oil demand were highly pessimistic.

2004 (Q2): One of the highest recorded levels of excess production by OPEC members; anticipated inventory buildup.

2005 (Q1): OPEC spare capacity levels hit record lows. Strong demonstrated demand and projected growth from China and the United States (U.S.). On the supply side, OPEC and market analysts express concerns over non-OPEC output. OPEC abandons its price band strategy amid consistent price growth and a shift in market fundamentals.

2008 (Q1): A decrease in inventories accompanies a surge in the oil price. Strong demand projections, especially for China, which started expanding its strategic petroleum reserve. Angola and Ecuador join OPEC in 2007.

Table 3. Estimation results: identified interventions.

Intervention type	Intervention period	Impact
Level***	2002 (Q1)	Negative
Level***	2004 (Q2)	Negative
Level***	2005 (Q1)	Positive
Level***	2008 (Q1)	Positive
Level***	2012 (Q2)	Positive

*** denotes statistical significance at 1%.

Source: KAPSARC research.

> 2012 (Q2): A 'perfect storm' emerges on the supply side: The 'Arab Spring' rages in the Middle East and North Africa region, Libya struggles under sanctions and descends into civil war, and the European Union (EU) imposes an oil embargo on Iran. Crude oil inventories sharply reduce and prices remain consistently high.

A number of seemingly substantial disruptions to the global and national oil markets did not emerge as interventions. The Iraq war and its subsequent relief of sanctions, insurgencies in Algeria and Angola, industry strikes in Venezuela and Kuwait and the financial crisis of 2008-2009 did not cause shifts in OPEC's quota targets. While these events substantially impacted national industries, the organization as a whole did not feel their effects. OPEC's reaction to such events is not limited to quota decisions. Member countries can respond to global supply disruptions by increasing their production, i.e., applying the 'emergency quota' mechanism between meetings to stabilize the market. This results in exceeding assigned quotas.

Similar to the OPEC target quotas, each member country's production function was subject to interventions identified in the estimation process. The majority of those interventions were muted on the organizational level and did not appear in the OPEC quota function, demonstrating OPEC's ability to balance the organization's output within the general strategy of balancing the oil market. The oil production of individual countries tends to be more vulnerable to external shocks (represented in the estimation) in the form of level breaks, slope breaks and outliers (see Table 4 for identified interventions for the sampled OPEC member countries).

This study analyzed the identified interventions and respective timestamps for Iran and Venezuela, to understand which events may cause external shocks to a given country's production function. The shifts in Iran's production trend – represented by level breaks – were caused by changes in the sanction policies enforced by the United Nations, U.S. and EU. Two negative breaks occurred at the end of 2001 and the second half of 2012. The end of 2001 saw the five-year extension of the United States' Iran and Libya Sanctions Act and the introduction of the USA Patriot Act that targeted Iranian financial institutions, including its central bank. The second level break in 2012 coincides with the imposition of the EU's oil embargo, the U.S. freezing the assets of the Iranian central bank, and an EU order to disconnect Iranian banks from the SWIFT network, the last of which heavily complicated Iran's export transactions with other economies. The positive level breaks in Iranian oil production, closer to the end of the studied period, reflect the process of sanction relief. The implementation of the Geneva Interim Agreement corresponds to the 2014 Q1 break, while the level breaks at the beginning of 2016 were likely triggered by major sanctions being lifted in January 2016. These include the oil exports embargo, investment restrictions and SWIFT disconnection.

Venezuela's output was primarily affected by its domestic political and economic problems. This contrasts to Iran, whose external shocks to oil production were caused by international complications. To an extent, **Venezuela's financial rating** and **political rating** coefficients (see Table 3) have captured its domestic problems. However, such shocks can create a larger than expected impact on oil production, such as the negative level break in 2002 or the slope break in 2015. They can also manifest in the form of outliers triggered by one-off events, a series of which occurred from 2001–2003.

Table 4. Estimation results: identified interventions.

Timeline, Year (Quarter)	Algeria	Iran	Saudi Arabia	Kuwait	Nigeria	Qatar	UAE	Venezuela
2001(4)	Level***	Level***						Outlier***
2002(1)								Level***
2002(3)						Outlier***		Outlier***
2002(4)	Outlier***							Outlier***
2003(1)							Outlier***	Outlier***
2003(2)	Outlier***		Level***			Level***		
2003(3)				Outlier***				
2004(3)			Outlier***					
2005(2)				Level***				
2006(1)				Level***				
2006(3)						Outlier***		
2006(4)				Level***				
2007(4)							Outlier***	
2008(4)						Outlier***		
2009(4)					Level***			
2010(2)			Level***					
2011(1)				Level***				
2011(4)				Outlier***				
2012(1)			Level***					
2012(2)						Level***		
2012(3)		Level***						
2012(4)	Level***							
2013(1)			Outlier***				Outlier***	
2014(1)		Level***						
2015(4)								Slope***
2016(1)		Level***						
2016(2)		Level***					Outlier***	

*** denotes statistical significance at 1%.
Red color denotes negative impact, blue denotes positive impact.

Source: KAPSARC research.

It is not easy to distinguish the particular events that are responsible for each identified external shock in the early 2000s. This period started with the re-election of Hugo Chavez in July 2000 and the introduction of a new Hydrocarbons Law at the end of 2001, which extended the government's control over the industry and natural resources. There was also a coup d'état attempt in April 2002 and a national strike from 2002-2003, among other potential external shocks to oil production. Another negative slope break occurred at the end of 2015 amid rising political tensions, currency devaluation and a declared state of 'economic emergency.' At this time, Petróleos de Venezuela, S.A., Venezuela's national oil company, was hit by a drop in the oil price. Macroeconomic instability and downgraded ratings made it difficult for the company to borrow money and pay subcontractors for upstream development (Platts 2016).

As with OPEC's quota decisions, such interventions make estimating OPEC members' oil output difficult. The output also demonstrates that such estimations have to be done on a country-by-country basis, further complicating the task. Moreover, individual countries tend to be more vulnerable to external shocks not captured by the dependent variables. In this regard, assessing the impact of specific national macroeconomic indicators could create further progress. However, this assessment may prove to be difficult, given the lack of availability and the low quality of macroeconomic data for OPEC member countries.

Conclusion

This analysis suggests that OPEC's quota decisions are driven by factors that reflect the state of the global oil market. These include the oil price, crude oil inventories, spare production capacity, global oil demand, six months projected demand and output from non-OPEC producers. The impact of **crude oil inventories** and the **output of non-OPEC producers** tends to be more significant in the short run. The elasticity coefficient of the **oil inventories** variable remains negative yet less pronounced in the long run, while the elasticity coefficient of the **non-OPEC output** variable turns from positive to slightly negative. These dynamics reflect the differences in OPEC's short-term and long-term responses to market conditions, and the organization's competing strategies of trying to balance the market and defending its market share.

Country-specific variables are found to be the main determinant of OPEC members' actual output. These variables include **spare production capacities**, and national economic, financial and political climates. The varied effects of these indicators point to a significant heterogeneity among OPEC member countries. However, a positive and significant effect of the **assigned quotas** on five out of eight sample countries suggests that OPEC plays a substantial role in determining the oil production of its members. OPEC also induces intra-organizational competitive behavior: each member whose oil production is affected by the assigned quotas tends to follow suit when the rest of the organization overproduces.

These complex patterns may have significant implications for OPEC's current strategy and projected output levels. The organization's market balancing strategy, employed since the end of 2016, is consistent with this study's estimates of members' long-term response to the market indicators (with an emphasis on the global oil inventories). Similarly, the analysis indicates less likelihood of coordinated action once members determine that the global oil market has rebalanced. Perhaps unsurprisingly, a sharp spike in non-OPEC oil output would be consistent with a return to coordinated production cuts.

It is more difficult to determine whether OPEC and its members will continue to deliver as strong a compliance record as that observed in 2017. This is due to three factors: first, the majority of the sampled member countries demonstrate a strong competitive behavior pattern in response to overproduction by other members. Second, a number of producers with significant capacity potential tend to be primarily affected by domestic political and economic conditions and can potentially ramp up their output from their current levels. Finally, a major factor that may have contributed to the strong compliance of 2017 is the production cut agreement reached with a number of non-OPEC producers, a framework not observed in the analyzed period.

External shocks tend to affect OPEC's quota decisions and its members' output levels; these are not captured by the identified variables. On the country level, these disruptions are usually of a political or macroeconomic nature and are generally one-off occurrences. Their impact tends to be limited to specific countries and does not register on the organizational level. They do not, therefore, affect quota decisions. External factors that impact the quota targets are either disruptions to the global oil market or a combination of market trends that trigger a synergetic effect leading to an exaggerated market response fueled by speculative behavior.

The impact of external shocks and other unobserved components remains extremely difficult to predict. As such, further research focused on member countries' economic and political indicators may progress the understanding of OPEC's production drivers. The demonstrated dual effect of the political, economic and financial indices calls for a disaggregated analysis of the relationship between macroeconomic, financial and political indicators and individual countries' oil production.

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Appendix A: Formulation of the Approach

A.1 Scope and method

This analysis covers OPEC target oil production levels and actual output from 2000 until 2016. Production targets are aggregated for the whole organization and represented on a quarterly basis by taking an average number for respective three months. The actual output is also analyzed on an aggregated quarterly level, but individually for each OPEC member country. This phase of the research omits Angola, Ecuador, Gabon, Iraq, Indonesia and Libya, as these countries were either not acting OPEC members during the entire period in focus or were engaged in military conflicts. Therefore, this analysis focuses the actual oil production drivers on Algeria, Iran, Kuwait, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates (UAE) and Venezuela.

This study applies a structural time series model (STSM). The general STSM formulation used in this analysis outlines relationships between the depended variables – production target and actual output. It also outlines several key determinants relating to the global oil industry performance and macroeconomics in the production target and the country-specific ones in the actual output. The STSM method also captures exogenous changes from unobserved components in the form of a underlying stochastic trend and includes interventions to account for the impact of one-off events or structural breaks, such as climatic irregularities, infrastructure disruptions or improvements in energy efficiency. See the text box below for the background on applying STSM models in economic and energy studies.

Structural time series models

Structural time series models provide a natural framework for modeling time-varying trends in measured data. The STSM modeling approach was first developed by Harvey (1989) and further refined over the years by Harvey and Scott (1994) and Harvey (1997). The distinguishing feature of such approach is the ability to decompose a time series not only into a trend – represented by slope and level – but also to account for cycles, seasonal and irregular components, and being able to provide a direct interpretation of such components. The flexibility of the model is achieved by letting the regression coefficients change over time. Models may also be constructed for multivariate series with the inclusion of explanatory and intervention variables.

Initially applied for a variety of macroeconomic analyses, e.g., looking at specific indicators such as gross domestic product (GDP), exports or interest rates, and forecasting financial and business cycles, the method has been used in the energy domain. The use of such models has scaled up recently, with many applications revolving around estimating energy demand patterns and the respective underlying trends across a range of sectors, fuels and regions. A similar novel approach can be implemented on the supply side, where the associated decision making involves unobserved components.

Sections A2 and A3, below, present a detailed formulation of the approach and relevant specifications for production targets, and the actual output of member countries. Note that a reduced form analysis was implemented where insignificant coefficients were dropped. The same set of initial variables (with and without lags) was used. The variables and coefficients presented are the ones that ended up being significant.

A.2 OPEC production targets

The applied STSM framework outlines the relationship between OPEC production targets and key determinants: real crude prices, inventories, current and expected world demand, OPEC's spare production capacity, real global GDP and non-OPEC output levels.

The function of the OPEC production target is thus identified in the form of

$$Q_t = f(P_t, INV_t, D_t, Y_t, Scap_t, NOprod_t, FutD_t, UPT_t) \quad \text{(A1)}$$

Where

Q_t Quarterly OPEC production target.

P_t Real price of OPEC basket crude oil.

INV_t Combined global inventories of all crude oil grades.

D_t Current world demand of crude oil.

$FUTD_t$ OPEC six months projection of global oil demand.

Y_t Combined real global GDP.

$SCAP_t$ Combined spare production capacity of all OPEC members.

$NOPROD_t$ Combined production of non-OPEC members.

UPT_t Underlying production trend.

The above equation is estimated using a dynamic auto-regressive lag specification defined as

$$q_t = \alpha_0 p_t + \beta_0 inv_t + \beta_1 inv_{t-1} + \gamma_0 d_t + \gamma_1 d_{t-1} + \delta_0 futd_t + \theta_0 y_t + \theta_1 y_{t-1} + \varphi_0 scap_t + \omega_0 noprod_t + \omega_1 noprod_{t-1} + UPT_t + \varepsilon_t \quad \text{(A2)}$$

Where q_t, p_t, inv_t, d_t, fut_t, y_t, $scap_t$ and $noprod_t$ are the natural logarithm of Q_t, P_t, INV_t, D_t, Y_t, $Scap_t$, $NOprod_t$, $FutD_t$, UPT_t in year t, respectively and ε_t is the random error term. As such, the coefficients α_0, β_0, γ_0, δ_0, θ_0, φ_0 and ω_0 denote the short-run impact elasticities for the aforementioned variables, respectively. A one-quarter lag has been implemented to reflect potential dynamic relationships based on the timeframe and frequency of the data used. Moreover, we used an independent variable, 'global GDP,' as a proxy for worldwide income, which, in turn, affects global oil demand.

The stochastic underlying trend (UPT) is defined in function of interventions as

$$UPT_t = \mu_t + \text{slope interventions} + \text{level interventions} + \text{irregular interventions} \quad \text{(A3)}$$

With

$$\mu_t = \mu_{t-1} + \phi_{t-1} + \eta_t; \qquad \eta_t \sim NID(0, \sigma_\eta^2) \quad \text{(A4)}$$

$$\phi_t = \phi_{t-1} + \zeta_t; \qquad \zeta_t \sim NID(0, \sigma_\zeta^2) \quad \text{(A5)}$$

And μ_t, ϕ_t being the level and slope of the trend, respectively. As expressed by Harvey and Sheppard (1993), the profile of the stochastic trend component is determined by the variables η_t and ζ_t as the uncorrelated white noise disturbances with variances σ_η^2 and σ_ζ^2, respectively. As illustrated in equation A3, interventions (irregular, slope and level) were inserted in the equation to facilitate the fit and passing the diagnostic test for residuals. The various interventions can be an informative source on structural changes and breaks for the period of this analysis.

The preferred parsimonious specification was obtained by estimating equations A2, A3 and A4 using STAMP 8.1 software (Koopman et al. 2000). Kalman filter and maximum likelihood were used as insignificant variables and were eliminated in a stepwise regression form. Interventions were added to the model while making sure that the model conforms to all diagnostic tests.

A.3 Actual oil output of OPEC member countries

The general formulation of the STSM applied outlines the relationship between the country oil production levels and several determinants: assigned quota, spare capacity, compliance of other members and financial, political and economic risk ratings.

The general function can be expressed in the form of

$$Q_t = f(ER_t, FR_t, PR_t, Quota_t, Scap_t, Othcomp_t, UPT_t)$$

Where:

Q_t	Quarterly production of a particular OPEC member country.
ER_t	Economic rating of the country.
FR_t	Financial rating of the country.
PR_t	Political rating of the country.
$QUOTA_t$	Production quota assigned to the country.
$SCAP_t$	Spare production capacity of the country.
$OTHCOMP_t$	Combined compliance of other OPEC members.
UPT_t	Underlying production trend of the country.

The above equation is estimated using a dynamic auto-regressive lag specification defined as

$$q_t = \alpha_0 quota_t + \beta_0 er_t + \beta_1 er_{t-1} + \gamma_0 fr_t + \gamma_1 fr_{t-1} + \theta_0 pr_t + \theta_1 pr_{t-1} + \varphi_0 scap_t + \varphi_1 scap_{t-1} + \omega_0 othcomp_t + \omega_1 othcomp_{t-1} + UPT_t + \varepsilon_t$$

Where *quota*, *er*, *fr*, *pr*, *scap* and *othcomp* are the natural logarithm of $Quota_t$, ER_t, FR_t, PR_t, $Scap_t$, $OTHCOMP_t$, UPT_t in year *t*, respectively and ε_t is the random error term. As such, the coefficients α_0, β_0, γ_0, θ_0, φ_0 and ω_0 denote the short-run impact elasticities for the aforementioned variables, respectively. The UPT specifications are similar to those underlined in the section pertaining to the OPEC production targets.

Appendix B: Data Sources

Table B1. Variables and data sources used in the OPEC production targets analysis.

Variable	Description	Units	Frequency	Source(s)
Q_t	OPEC production target.	Mbbl/d	Monthly, transferred to quarterly by taking three-months average value.	OPEC 2017
P_t	Real price of OPEC basket crude oil.	$(2010)/ Mbbl/d	Monthly, transferred to quarterly by taking three-months average value; discounted.	OPEC 2017
INV_t	Combined global inventories of all crude oil grades (net inventory withdrawals).	Mbbl/d	Monthly, transferred to quarterly by taking three-months average value.	OPEC 2017, EIA 2017
D_t	Current world demand of crude oil.	Mbbl/d	Quarterly	OPEC 2017
$FUTD_t$	OPEC six months projection of global oil demand.	Mbbl/d	Quarterly	OPEC 2017
Y_t	Combined real global GDP.	$(2010)	Quarterly; discounted	CEIC 2017
$SCAP_t$	Combined spare production capacity of all OPEC members.	Mbbl/d	Quarterly	OPEC 2017, EIA 2017
$NOPROD_t$	Combined production of non-OPEC members.	Mbbl/d	Quarterly	EIA 2017
UPT_t	Underlying production trend of the country.	Mbbl/d	Quarterly	KAPSARC estimations

Source: KAPSARC.

Table B2. Variables and data sources used in the OPEC members actual output analysis.

Variable	Description	Units	Frequency	Source(s)
Q_t	Production of a particular OPEC member country.	Mbbl/d	Monthly, aggregated on the quarterly basis.	EIA 2017
ER_t	Economic rating of the country.	Composite index	Monthly, transferred to quarterly by taking three-months average value.	PRS 2017
FR_t	Financial rating of the country.	Composite index	Monthly, transferred to quarterly by taking three-months average value.	PRS 2017
PR_t	Political rating of the country.	Composite index	Monthly, transferred to quarterly by taking three-months average value.	PRS 2017
$QUOTA_t$	Production quota assigned to the country.	Mbbl/d	Monthly, transferred to quarterly by taking three-months average value.	OPEC 2017
$SCAP_t$	Spare production capacity of the country.	Mbbl/d	Quarterly	EIA 2017
$OTHCOMP_t$	Combined compliance of other OPEC members.	Ratio	Quarterly $(QUOTA_{OPEC}\text{-}QUOTA_t)/(Q_{OPEC} - Q_t)$	EIA 2017, OPEC 2017, KAPSARC calculations
UPT_t	Underlying production trend of the country.	Mbbl/d	Quarterly	KAPSARC estimations

Source: KAPSARC.

Appendix C: Estimation Output

Table C1. Preferred specification: OPEC quota decisions.

Estimated coefficients	
α_0	0.078***
β_0	-1.037***
β_1	0.750***
γ_0	0.615**
γ_1	-
δ_0	0.536**
θ_0	-
θ_1	-
φ_0	-0.069***
ω_0	0.596*
ω_1	-0.659**
Variances	
Irregular	0.00016
Level	0.00035
Slope	0.0000
Interventions	
	Level 2002(1) ***
	Level 2004(2) ***
	Level 2005(1) ***
	Level 2008(1) ***
	Level 2012(2) ***
Goodness of fit	
p.e.v.	0.00019
AIC	-7.98
R^2	0.975
R_d^2	0.882
Residual diagnostics	
Std. error	0.014
Normality	1.606
$H_{(h)}$	$H_{(15)} = 0.750$
$r_{(1)}$	-0.069
DW	2.018
$Q_{(p.d)}$	$Q_{(8,3)} = 2.722$
Predicted failure	1.35

Source: KAPSARC.

Appendix C: Estimation Output

Table C2. Preferred specification: OPEC members' actual output.

Estimated coefficients	Algeria	Iran	Saudi Arabia	Kuwait	Nigeria	Qatar	UAE	Venezuela
α_0	-	0.423***	0.632***	0.794***	-	0.703***	0.564***	0.064**
β_0	0.094**	-	-	-	-	0.230**	-	-
β_1	-	-	-	-	0.372***	-	-	-
γ_0	-	-	-	-	0.261***	-	0.282***	0.110***
γ_1	-0.164**	-	-	-	-0.368***	0.238**	-	-
θ_0	0.536**	-0.179*	-	-	-	-	-	-0.238***
θ_1	-	-	-	-	-	-	-0.336***	-0.091*
φ_0	-0.002*	-	0.004***	-0.009***	-0.013***	-0.004***	-0.039***	-0.002***
φ_1	-	-0.003***	-0.098***	-0.002**	-0.006***	-	-	-
ω_0	-0.130*	0.453***	-	0.374***	-	0.814***	0.340***	-
ω_1	-	0.236***	0.115*	-	-	-	-	-
Variances								
Irregular	0.00000	0.00000	0.00008	0.00007	0.00061	0.00000	0.0000	0.000011
Level	0.00015	0.00012	0.0001	0.0001	0.00000	0.00027	0.00016	0.0001
Slope	0.000021	0.000013	0.0000	0.0000	0.000023	0.00000	0.00000025	0.000009
Interventions	Level 2001(4) *** Outlier 2002(4) *** Outlier 2003(2) *** Level 2012(4) ***	Level 2001(4) *** Level 2012(3) *** Level 2014(1) *** Level 2016(1) *** Level 2016(2) ***	Level 2003(2) *** Outlier 2004(3) *** Level 2010(2) *** Level 2012(1) *** Outlier 2013(1) ***	Outlier 2003(3) *** Level 2005(2) *** Level 2006(1) *** Level 2006(4) *** Level 2011(1) *** Outlier 2011(4) ***	Level 2009(4) ***	Outlier 2002(3) *** Level 2003(2) *** Outlier 2006(3) *** Outlier 2008(4) *** Level 2012(2) ***	Outlier 2003(1) *** Outlier 2007(4) *** Outlier 2013(1) *** Outlier 2016(2) ***	Outlier 2001(4) *** Level 2002(1) *** Outlier 2002(3) *** Outlier 2002(4) *** Outlier 2003(1) *** Slope 2015(4) ***
R^2	0.783	0.889	0.863	0.870	0.603	0.776	0.890	0.98
Residual diagnostics								
Std. error	0.014	0.013	0.013	0.013	0.032	0.016	0.012	0.011
Normality	0.492	2.09	0.450	3.586	2.742	7.24	0.435	2.081
$H_{(h)}$	$H_{(18)} = 0.844$	$H_{(17)} = 0.541$	$H_{(18)} = 1.152$	$H_{(17)} = 1.079$	$H_{(18)} = 0.717$	$H_{(17)} = 0.398$	$H_{(17)} = 0.719$	$H_{(17)} = 0.258$
$r_{(1)}$	-0.058	0.066	0.103	0.117	-0.061	0.080	0.078	-0.166
DW	2.014	1.847	1.765	1.743	2.025	1.578	1.752	2.137
$Q_{(p.d)}$	2.433	6.151	20.27	5.695	14.74	4.729	7.955	22.36

Source: KAPSARC.

Notes for Tables C1, C2:

1) STAMP 8.10 was used to estimate the preferred specifications and diagnostic tests.

2) The estimation period runs from Q1-2000 to Q4-2016.

3) *,** and *** denotes statistical significance at 10%, 5% and 1% respectively.

4) AIC is the Akaike information criterion and p.e.v. is the prediction error variance.

5) R^2 is the coefficient of determination and R_d^2 the coefficient of determination based on difference.

6) Normality is the Bowman-Shenton test.

7) $H_{(h)}$ is the test for heteroscedasticity.

8) $r_{(1)}$ is the residual autocorrelations at lag 1 distributed as N(0, 1/T).

9) DW is the Durbin-Watson test statistic.

10) $Q_{(p.d)}$ is the Box-Ljung statistic based on the residual autocorrelation of the first *p*.

Notes

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About the Study

An Estimation of the Drivers Behind OPEC's Quota Decision Making and Members' Compliance is a joint study undertaken by the King Abdullah Petroleum Studies and Research Center (KAPSARC) and China's National Petroleum Corporation, Economics and Technology Research Institute (CNPC ETRI). It is part of a broader collaborative initiative aimed at improving the understanding of international decision making, to better engage in global energy governance.

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