OPEC, Saudi Arabia, and the Shale Revolution:
Insights from Equilibrium Modelling and Oil Politics
Dawud Ansari, DIW Berlin & EADP
Vienna, 4th September, 2017
2014 – 2016: Oil price crash, following US shale growth and an OPEC decision not to cut production

Previous literature: No consensus on OPEC’s intention
• OPEC defeat, OPEC attack, or OPEC experiment?

Bathtub model to examine if static competition can explain price developments consistently over time

Qualitative discussion about oil politics of OPEC and Saudi Arabia in particular

Conclusions:
• OPEC decision most likely an attempt to drive out shale and to test for shale elasticity
• Shale oil might have altered competition permanently, but OPEC is still an important player
Content

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2. A (not-so) simple model of the crude oil market
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Background:

Developments and scientific discourse
Background

WTI quarterly price. Data: Thomson Reuters

Crude oil production capacities
Data: IEA, own calculations

Price drop
Nov. 2016
Production cut agreed (incl. Russia, Iran)

Price collapse
Feb 2016
Russia signals interest in cuts

Jun 2016
OPEC deal talks fail

Dec 2015:
Vienna talks: Still no cuts

Vienna talks: No OPEC cuts
Nov 2014
No literature consensus

- **Shale oil revolution** (e.g. Aguilera and Radetzki, 2015)
- **Financial speculation** (e.g. Fantazzini, 2016, Tokic, 2015)
- **Dampened demand** (e.g. Baumeister and Kilian, 2016)
- **New economics of oil** Dale (2016)
- **OPEC Behaviour**
- **Geopolitical stabilisation** (e.g. Baffes et al., 2015)

- **OPEC floods the market to drive out shale**
  - Behar and Ritz (2017)
  - Coy (2015)
  - Gause (2015)
  - Mănescu and Nuño (2015)

- **OPEC lost its position as the swing supplier to shale**
  - Baffes et al. (2015)
  - Baumeister and Kilian (2016)
  - Dale (2016)
  - Kaletsky (2015)
  - The Economist (2015)

**Uncertainty**
- Fattouh et al. (2016)
- Huppmann and Livingston (2015)
OPEC’s own interpretation

“[Ali al-Naimi’s] biggest move was the latest one of defending Saudi market share, and abandoning the OPEC swing role.”

Mohammad al-Sabban, June 2015

[...] It is not in the interest of OPEC producers to cut their production. [...] Whether [the price] goes down to $20/B, $40/B, $50/B, $60/B, it is irrelevant. [...] But if it goes down, others will be harmed greatly before we feel any pain.

Ali al-Naimi, November 2014

OPEC states:
We will flood the market and defend our market share!

Does history back this decision?
Is OPEC a cartel?

And even worse: How to model that?

Fattouh and Mahadeva (2013): Changing OPEC objectives and behaviour over time make it impossible to have a single model explaining all OPEC history.
A (not-so) simple model of the crude oil market
Model description

**Bathtub market**
- Homogeneous crude
- **Pool model**: Unified, *global demand* function
- **Relaxation**: quality adjustment

**Present profit maximisation**
- **No dynamic** strategic behaviour
- Full information and certainty

**Golombek production costs**

**Linear demand**
- From actual demand and fixed elasticity

An extension of Huppmann (2013)

\[
\max_{q_{it}} \{ p_t(\cdot)q_{it} - C_{it}(q_{it}) \mid q^S_{-it} \} \ \forall i, t
\]

t: 2011 Q4 – 2015 Q4, quarterly
## Data & Implementation

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>IEA (29 suppliers with 94.4% of global supply)</td>
</tr>
<tr>
<td>Capacities</td>
<td>OPEC: IEA, non-OPEC: 97% of output rule and IEA (e.g. Behar &amp; Ritz, 2017)</td>
</tr>
<tr>
<td>Production costs</td>
<td>DIW data set (e.g. Langer et al, 2016)</td>
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<tr>
<td>Oil quality adjustment</td>
<td>Calculations based on US Dept. of Energy, EIA, Oil &amp; Gas Journal</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>Survey-based: Javan &amp; Zahran (2015), Caldara et al. (2016)</td>
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<table>
<thead>
<tr>
<th>Setup</th>
<th>Formulation</th>
<th>Solver</th>
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<tbody>
<tr>
<td>Cournot, Perfect Comp.</td>
<td>MCP</td>
<td>PATH</td>
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<tr>
<td>Stackelberg</td>
<td>MPEC (\rightarrow) MINLP</td>
<td>Bonmin, Couenne</td>
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**Share in global crude production capacities**

- **Gini coefficient:** 0.505
- **Data:** IEA and own calculations
Results: Price trajectories

Actual and computed price trajectories

Goodness of fit

<table>
<thead>
<tr>
<th>ARME in %</th>
<th>KSA-FR</th>
<th>PC</th>
<th>KSA-CO</th>
<th>Cournot</th>
<th>UNI-CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>23</td>
<td>27</td>
<td>35</td>
<td>52</td>
<td>120</td>
</tr>
<tr>
<td>First period</td>
<td>25</td>
<td>31</td>
<td>24</td>
<td>43</td>
<td>121</td>
</tr>
<tr>
<td>Second period</td>
<td>18</td>
<td>18</td>
<td>63</td>
<td>75</td>
<td>119</td>
</tr>
</tbody>
</table>
Computed profits (left) and production quantities (right) in the United OPEC setup in Q1 2015 by Saudi Arabia (KSA) and other OPEC members.
Results: Sensitivity analysis

Robustness of the perfect competition results to cost variations (overall cost reductions in %)
Qualitative discussion:
Oil Politics
Saudi calculus: Revenues or market-shares?

- **Trade-off** between revenue maximisation and market-shares
- Prolonged low oil prices can result in economic and political havoc
- Geopolitical impact ambiguous, Saudi Arabia advances in refining, Vision 2030
- A toughened oil market endangered by **peak-demand** (climate policies, alternative tech.)
  - Green paradox?
- Similarities to the 1980s?
- Saudi-Arabia’s priority in deal negotiations:
  - No moral hazard!
  - No self-harm
- Influence of domestic politics?

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Shale Performance under Pressure

- Shale economics: Different cooperative, financial, and cost structure
- Severe *overvaluation of shale breakeven* before the drop
- Potential misunderstanding of the breakeven concept itself (Kleinberg et al., 2016)
- Significant decrease in production, although far below OPEC hopes (OPEC, 2016)

Month-to-month and quarter-to-quarter changes in US rigs (left) and quarter-to-quarter and year-to-year changes in US daily crude oil production (right). Data: EIA
Summary & Conclusion
Conclusion

• Prices **before the drop** are consistent with **static short-term profit maximisation**.

• **Prices after the drop** can hardly result from such a behaviour but rather from **dynamic calculus or information-revealing behaviour**.

• Shale oil might have altered competition permanently, but **OPEC stays an important player** in the market.

• Oil can potentially continue to move in a price corridor, defined by mutual incentives and technology

• Modelling OPEC is anything but trivial.
Thank you for your attention.
References

- Dale, S., 2016. New Economics of Oil. Oil and Gas, Natural Resources, and Energy Journal 1, 3.
References (cont’d)

- OPEC, 2016. World Oil Outlook.
Backup
## Model notation

**Set Indices**

| $i \in I$ | Crude oil producing countries |
| $j \in J \subseteq I$ | Stackelberg leaders |
| $k \in K \subseteq I$ | Stackelberg followers |
| $t \in T$ | Time periods in quarterly steps from 4th quarter 2011 onwards |

**Parameters**

| $\beta_{1t}, \beta_{2t}$ | Demand parameters |
| $\varepsilon$ | Price elasticity |
| $\varphi_t$ | Observed actual price |
| $\chi_t$ | Observed actual quantity |
| $\gamma_{1i}, \gamma_{2i}, \gamma_{3i}$ | Cost parameters |
| $\kappa_{it}$ | Production capacity |
| $\eta_i$ | Quality of oil index |

**Variables**

| $p_t \in \mathbb{R}_0^+$ | Market price in period $t$ |
| $q_{it} \in \mathbb{R}_0^+$ | Quantity supplied by producer $i$ in period $t$ |
General relationships

\[ C_{it}(q_{it}) = \gamma_1 i q_{it} + \gamma_2 i q_{it}^2 - \gamma_3 i (q_{it} - \kappa_{it}) \left( \ln \left( 1 - \frac{q_{it}}{\kappa_{it}} \right) - 1 \right) \]

\[ \Rightarrow M C_{it} \equiv \frac{\partial C_{it}}{\partial q_{it}} = \gamma_1 i + 2 \gamma_2 i q_{it} - \gamma_3 i \ln \left( 1 - \frac{q_{it}}{\kappa_{it}} \right) \]

\[ p_t = \beta_{1t} + \beta_{2t} \sum_{i \in I} q_{it} \]

\[ \beta_{1t} = \varphi_t (1 - \varepsilon^{-1}) \]

\[ \beta_{2t} = \varphi_t (\chi_t \varepsilon)^{-1} \]

\[ q_{it} \leq \kappa_{it} \]
Perfect competition KKTs

\[ 0 \leq p_t - \eta_{it} MC_{it} \perp \kappa_{it} - q_{it} \geq 0 \quad \forall i \in I \quad \forall t \in T \]

\[ MC_{it} = \gamma_1 i + 2\gamma_2 i q_{it} - \gamma_3 i \ln \left( 1 - \frac{q_{it}}{\kappa_{it}} \right) \quad \forall i \in I \quad \forall t \in T \]

\[ p_t = \beta_1 t + \beta_2 t \sum_{i \in I} q_{it} \quad \forall t \in T \]
Cournot KKTs

\[ 0 \leq p_t - \eta_{it} M C_{it} - \tau_i \perp \kappa_{it} - q_{it} \geq 0 \quad \forall i \in I \quad \forall t \in T \]

\[ M C_{it} = \gamma_{1i} + 2\gamma_{2i} q_{it} - \gamma_{3i} \ln \left( 1 - \frac{q_{it}}{\kappa_{it}} \right) \quad \forall i \in I \quad \forall t \in T \]

\[ p_t = \beta_{1t} + \beta_{2t} \sum_{i \in I} q_{it} \quad \forall t \in T \]
Stackelberg MINLP

\[
\max_{q_{jt}} \left\{ p_t \sum_{j \in J} q_{jt} - \sum_{j \in J} \left[ \eta_{jt} C_{jt} + \tau_j q_{jt} \right] \right\} \quad \forall t \in T
\]

\[
C_{jt} = \gamma_1 q_{it} + \gamma_2 q_{it}^2 - \gamma_3 \left( q_{it} - \kappa_{it} \right) \left( \ln \left( \frac{q_{it}}{\kappa_{it}} \right) - 1 \right) \quad \forall j \in J \quad \forall t \in T
\]

\[
0 \leq p_t + (1 - f) \beta_{2t} q_{kt} - \eta_{kt} M C_{kt} \quad \forall k \in K \quad \forall t \in T
\]

\[
M C_{kt} = \gamma_{1k} + 2\gamma_{2k} q_{kt} - \gamma_{3k} \ln \left( \frac{q_{kt}}{\kappa_{kt}} \right) \quad \forall k \in K \quad \forall t \in T
\]

\[
0 \leq \kappa_{it} - q_{it} \quad \forall i \in I \quad \forall t \in T
\]

\[
p_t = \beta_{1t} + \beta_{2t} \sum_{i \in I} q_{it} \quad \forall t \in T
\]

\[
p_t + (1 - f) \beta_{2t} q_{kt} - \eta_{kt} M C_{kt} \leq r_{kt} BIG \quad \forall k \in K \quad \forall t \in T
\]

\[
\kappa_{it} - q_{it} \leq (1 - r_{kt}) BIG \quad \forall k \in K \quad \forall t \in T
\]