Output Adjusting Cartels Facing Dynamic, Convex Demand under Uncertainty: The Case of OPEC

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Motivation

Recently many VAR applications focusing on speculation vs fundamentals with mixed results, e.g., Kilian, Kisecki, Kaufman, Büyüksahin and Harris, Juvenal and Petrella, Lammerding, Stephan, Trede and Wilfling, Hache and Lantz, etc.

Accounting for dynamic demand is crucial (all papers in the tradition of Griffin assume static demand)

Gately’s explicit analysis of OPEC’s profit motives.

Economics vs politics

Quantity setting cartels (Hyndman, Wirl, IJIO)

Uncertainty
Economics vs Politics

**Traditional Economics:** Politics has little influence, economics rules the world.
Adam Smith, "It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address our-selves not to their humanity but to their self-love and never talk to them of our own necessities but of their advantage."

**Public Choice:** Politicians have private interests.
John Stuart Mill, "The very principle of constitutional government requires it to be assumed, that political power will be abused to promote purposes of the holder; not because it is always so, but because such is the natural tendency of things to...

Buchanan-Tullock: ".. that the individual must somehow shift his psychological and morale gears when he moves between the private and social aspects of life."

**Politics dominates economics up to the medium term and economics is only a weak constraint.**
Proof: former Socialist economies.
Examples from energy: BP (Yom Kippur war, Iranian revolution, Iraq wars)
Recently – Russia: gas embargoes, Ukraine.
oil market

Adelman: Not as Arabs or Muslims or other irrelevancy, but as rational economic actors, the OPEC countries must take the money and run.
Political constraints imply short run oriented policies, in particular in the Middle East.

Assumptions:
- Sluggish demand
- Anti-Western sentiments (Pareto)
- rational politicians

Embargoes/price hikes can be optimal for politicians, yet politics lacks explanatory power in recent cases of OPEC (not Russia!). Israel’s invasion of Lebanon/Gaza in 2006 was a causa prima to be exploited for political currency.

This raises also doubts about past references to past events (Yom Kippur war, Iranian revolution, etc.).
Prices vs Quantities

- Past – price and tax strategies but
- Recently, **dominance of quantity strategies:** demand - permits instead of taxes *ETS, Waxman-Markey*
Prices vs. Quantities
M. Weitzman (1974)
Review of Economic Studies 41: 477-491

\[a \text{E}[MB] \text{ indicates expected marginal benefits, } \text{E}[MC] \text{ indicates expected marginal costs, and } MC_1 \text{ and } MC_2 \text{ indicate alternative cost outcomes.}\]

Figure taken from Pizer
Supply:
OPEC: Prices and quotas

Crude oil prices 1861-2009
US dollars per barrel
World events
- Pennsylvania oil boom
- Russian oil exports began
- Sumatra production began
- Discovery of Spindletop, Texas
- Growth of Venezuelan production
- East Texas field discovered
- Post-war reconstruction
- Iran nationalization
- Oil crisis
- Yom Kippur War
- Iraq invaded Kuwait
- Invasion of iraq

prices
royalties + reference price

Foundation of OPEC
1960

quotas

Foundation of OPEC
1960

off-sellng price
Prices vs Quantities

Wirl (JEEM 2012): In a strategic setting between consumers and producers facing global warming, quantities are inferior to prices (taxes)

Mystery – both sides choose currently quantities

Lacking an economic explanation, political motives may provide the answer, e.g.,

**consumer governments** do not want to use the t-word anymore and want to hide the costs of fighting global warming,

**cartels** find it easier to agree on changes in production than to fix prices if only to avoid anti-trust law enforcement. OPEC was happy to blackmail markets & speculation for high prices
Economic Model - Quota adjusting OPEC

Dynamic & stochastic and convex demand $x$

$$dx(t) = \eta(D(p(t)) - x(t)) \, dt + \alpha(x(t)) \, dzd(t)$$

Dynamic & stochastic supply $y$

$$dy(t) = u(t) \, dt + \beta(y(t)) \, dzs(t).$$

Max. expected NPV $V(x_0)$

$$V(x_0) = \max_{\{u(t)\in U=[-\bar{u},\bar{u}]\}} E \left[ \int_0^\infty e^{-rt} p(t)y(t) \, dt \right]$$

Market clearing price $p(t)$

$$p(t) = D^{-1} (y(t) + \tau u(t) - \tau (\alpha dzd(t) - \beta dzs(t)))$$

Market clearing price $p^e(y + \tau u)$

$$p^e(y + \tau u) = \int_{-\infty}^\infty \int_{-\infty}^\infty e^{-\frac{\nu^2}{2}} \frac{1}{\sqrt{2\pi}} e^{-\frac{\omega^2}{2}} \frac{1}{\sqrt{2\pi}} D^{-1} (y + \tau u - \tau \alpha v + \tau \beta w)$$
Optimal Strategy – convex demand

\[ rV(y) = \max_{u \in U = [-\bar{u}, \bar{u}]} \left\{ yp^e(y + \tau u) + uV'(y) + \frac{1}{2} \beta^2 V''(y) \right\} \]

\[ u(y) = \begin{cases} \bar{u} & \text{if } y \leq \tilde{y} \\ -u & \text{if } y > \tilde{y} \end{cases} \]

\[ \tilde{y} : V'(\tilde{y}) + \frac{pe(\tilde{y} + \tau \bar{u}) - pe(\tilde{y} - \tau u)}{\bar{u} + u} \tilde{y} = 0 \]

Assuming exponential demand -> closed form solution of value functions

\[ q = e^{-q} K(q) + c_1 e^{\frac{\sqrt{2r\sigma^2 + v_m^2} - v_m}{\sigma^2}} q, \quad q < \hat{q}, \quad K(q) = \frac{4(rq + v_m - \sigma^2) + 2q(2v_m - \sigma^2)}{(2r + 2v_m - \sigma^2)^2} e^{(1-)} \]

\[ q = e^{-q} \bar{K}(q) + k_2 e^{\frac{v_m - \sqrt{2r\sigma^2 + v_m^2}}{\sigma^2}} q, \quad q > \hat{q}, \quad \bar{K}(q) = \frac{4(rq - v_m - \sigma^2) - 2q(2v_m + \sigma^2)}{(2r - 2v_m - \sigma^2)^2} e^{(1-)} \]
Application to OPEC

Demand $D(p) = 214.21 - 40\ln p$ and linear $D(p) = 80 - \frac{1}{2}p$ for comparison (calibrated to fit Gately (2007) and 30 mb/d exports for $100/b$)

$r = 0.05$, $\nu_m = 0.025 = 1$ mb/d = $u_m$, $\alpha = \beta = 2$ mb/d, $\tau = 10$

demand and supply uncertainty with standard errors of 2mb/d respectively
Rolling regression (window size 15) for the quadratic coefficient and ±2 standard error fitting for fitting () to OPEC oil exports based on BP 2011 complemented by OPEC’s Annual Statistical Bulletin 2011 for information in BP (2011) missing on some OPEC member countries’ consumptions.

Convex or linear demand is not implausible
Optimal Switching Level & Sensitivity

\[
\begin{align*}
\hat{y}(r) \\
\hat{y}(B) \\
\hat{y}(\tau)
\end{align*}
\]

mb/d

parameters \((r, B, \tau)\) relative to the reference case

\[
\begin{align*}
\hat{y}(\beta) \\
\hat{y}(u_m)
\end{align*}
\]

mb/d

parameters \((\beta, u_m)\) relative to the reference case
Price realizations due to shocks (10 realizations of $dz$ and $d\zeta$ respectively) and the corresponding optimal output adjustments at four different levels of demand: $r = 0.05$, $v_m = 0.025$ ($= 1$ mb/d), $\alpha = \beta = 0.05$ ($= 2$ mb/d), $\tau = 10$, and $A = 5.382$, $B = 1/40$. 

Prices at low demand

High prices at low demand

Low prices at high demand
Comparison OPEC Cartel vs Duopoly based on Wirl (IJIO, 2010)

Deterministic, adjustment costs, & linear demand

Exp. demand & stochastic

OPEC

Exp. demand & stochastic

Exports (mb/d)

\( \hat{y} \)

\( u^m \)

\(-u^m\)
Oil price changes across OPEC’s price and quantity policy.

price policy (official selling price)

(recent) quantity adjustment policy
Final remarks

Oil prices (unhappy with the dominant VAR approach)
Politics vs Economics (favors economics for OPEC and oil but politics remains a persistent threat, just now Russia-Ukraine)
Prices vs Quantities (mystery or due to politics?)
Optimal quantity adjustment policy facing dynamic, convex and stochastic demand leads to drastic price changes across a threshold but to less radical price changes as a price strategy.
This finding is compatible with actual observations
OPEC may not be a perfect cartel but already a hypothetical duopoly would lead to much larger supplies (above 70 mb/d)
Thank You for Your Attention!

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