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Determinants of Global Oil Production – Empirical Evidence for more than short run Cartel Rent Maximization

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Aleksandar Zaklan
Georg Zachmann
Anne Neumann

Agenda

1. **Introduction**
2. **Data and Methodology**
3. **Results and Discussion**
4. **Conclusions**

References

Motivation

- **Crude oil production and prices are key economic variables, but understanding of their interaction over time and for different producers is incomplete**
- **We analyze the dynamic response of crude oil output to past prices and other important control variables**
- **Disentangle determinants of global oil production by major country groups and on individual country level**
  - **OPEC, OECD and non-OECD/non-OPEC production**
  - **Individual country analysis**
- **Address methodological issues in the literature**
- **Isolate price effect more clearly than the literature does**

State of the Literature

- **Two major streams: models evaluating consequences of physical attributes/exhaustibility and tests of strategic producer behavior**
- **Physical attributes:**
  - **Hotelling (1931): resource exhaustibility**
  - **Hubbard (1956): oil depletion**
    - **Results are sensitive to assumptions**
- **Strategic behavior:**
  - **Griffin (1985): empirical testing of popular hypotheses: Cartel behavior, competitive behavior, revenue targeting**
    - **No thorough dynamic analysis exists**
    - **Methodological issues call into question validity of results**
- **We analyze the determinants of output, without specifically testing hypotheses**

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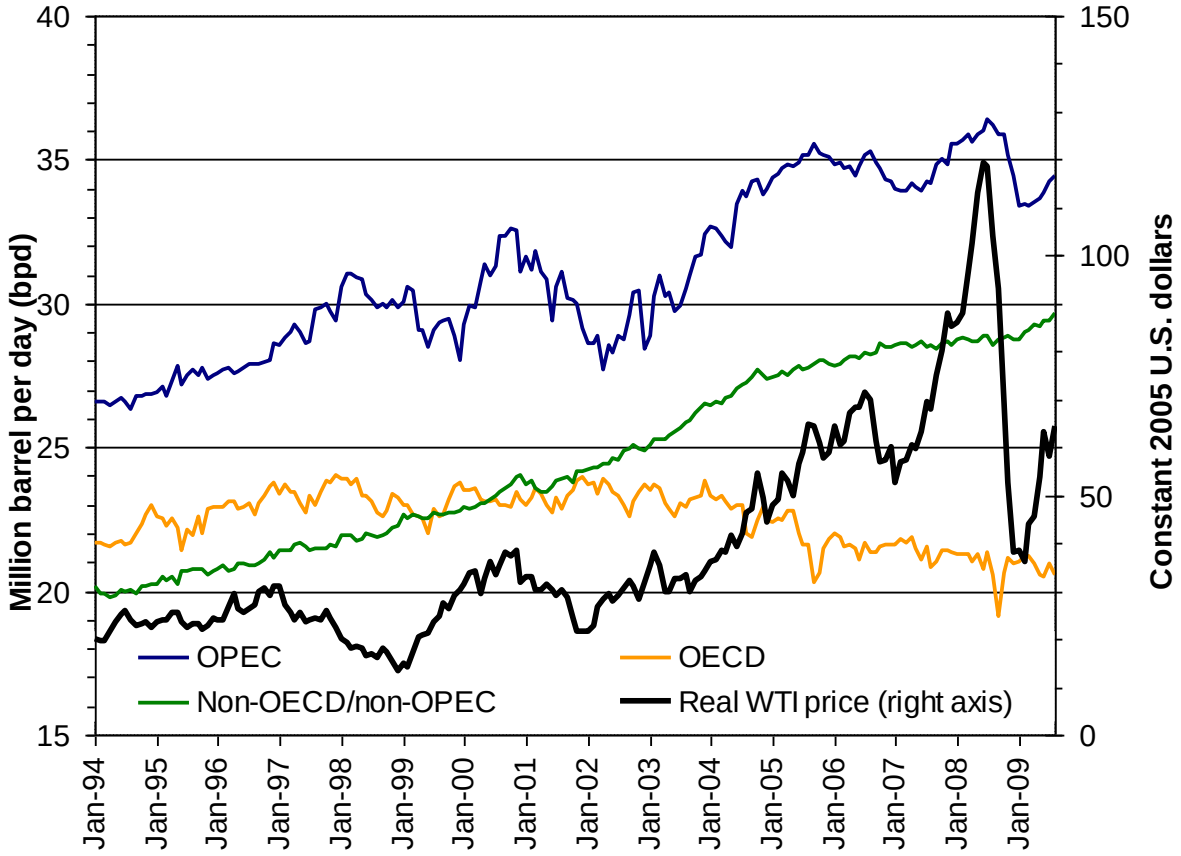
Data

- **Comprehensive country-level dataset at (mostly) monthly frequency**
  - **Global oil production**
  - **WTI oil price**
  - **Real economic activity/aggregate global demand**
    - **Baltic Dry Index (monthly averages of daily data)**
  - **Investment in oil production capacity**
    - **Rig count (Baker Hughes Inc.)**
  - **Institutional quality**
    - **Six indicators from World Bank's Worldwide Governance Indicators (WGI)**
      - Voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, control of corruption

Descriptive Analysis



OECD: stable and slightly declining trend, with sharp movements

OPEC: appears to mirror development in oil price, with a certain delay

Non-OECD/non-OPEC: smoothly increasing, broadly in line with trend in price

Hypotheses

Hypothesis 1:

Crude oil output responds to prices and other control variables over a range of lags from the short to the long term.

Hypothesis 2:

The response is heterogeneous among the three main groups of countries, OPEC, OECD and non-OECD/non-OPEC, as well as on the level of individual countries.

Methodology

- **Address stationarity issue by applying *Hodrick-Prescott-Filter* (HP) to all variables**
- **Two-step estimation strategy:**
  1. **Auxiliary regressions of real activity and rig count on prices**
     - **Purge price effect from proxies for investment and real activity**

$$RIG_{t,i} = \alpha_i + \sum_{s=0}^{S} \beta_{s,i} WTI_{t-s} + \varepsilon_{t,i} \qquad BDI_t = \varphi + \sum_{s=0}^{S} \gamma_s WTI_{t-s} + \mu_t$$

  2. **Main regression using residuals from auxiliary regressions**

$$Q_{t,i} = \omega_i + \sum_{k=1}^{K} \delta_{k,i} WTI_{t-k} + \sum_{l=1}^{L} \theta_{l,i} \overline{I}_{t-k,i} + \sum_{m=1}^{M} \tau_{m,i} \overline{REAL}_{t-m} + \Psi_i INST_{t,i} + \eta_{t,i}$$

     - **Clearer identification of effect of prices on quantities**

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Role of Prices: Group Level

	No controls			All controls		
	(1)	(2)	(3)	(4)	(5)	(6)
	OPEC	OECD	non-OECD/ non-OPEC	OPEC	OECD	non-OECD/ non-OPEC
Real WTI Price, monthly average (-1)	-0.0253*	-0.0189	-0.00508	0.00543	-0.000294	-0.00119
	(0.039)	(0.081)	(0.354)	(0.607)	(0.975)	(0.856)
Real WTI Price, monthly average (-2)	0.0507**	-0.00157	-0.00222	0.0801*	-0.0122	-0.00974
	(0.004)	(0.941)	(0.748)	(0.018)	(0.169)	(0.316)
Real WTI Price, quarterly average (-1)	0.000891	-0.00372	0.00878*	0.0389	-0.0777**	0.0225
	(0.963)	(0.676)	(0.016)	(0.247)	(0.002)	(0.082)
Real WTI Price, quarterly average (-2)	-0.0472	0.0391***	-0.0136*	0.0623	0.0618*	-0.0155
	(0.069)	(0.001)	(0.033)	(0.393)	(0.020)	(0.601)
Real WTI Price, quarterly average (-3)	0.0473***	-0.0157	0.00255	0.0716	-0.0557	0.0197*
	(0.001)	(0.265)	(0.815)	(0.222)	(0.061)	(0.020)
Real WTI Price, yearly average (-1)	-0.186***	0.0715**	-0.0211	0.379	0.00130	0.0503
	(0.000)	(0.002)	(0.079)	(0.297)	(0.993)	(0.419)
Real WTI Price, yearly average (-2)	-0.419***	0.0974**	-0.0585***	0.357	-0.157	0.0131
	(0.000)	(0.001)	(0.000)	(0.202)	(0.263)	(0.875)
Real WTI Price, yearly average (-3)	-0.288***	0.179***	-0.0650***	0.404	-0.448	-0.140
	(0.000)	(0.000)	(0.001)	(0.222)	(0.099)	(0.167)
Real WTI Price, yearly average (-4)	-0.355***	0.153***	-0.0613**	-0.0537	-0.602*	-0.261
	(0.000)	(0.000)	(0.003)	(0.780)	(0.035)	(0.333)
Real WTI Price, yearly average (-5)	-0.103*	0.146***	-0.0164	-0.0489	-0.778*	-0.201
	(0.043)	(0.000)	(0.393)	(0.858)	(0.041)	(0.335)
Real WTI Price, yearly average (-6)	-0.0238	0.0411	0.0302	-0.740*	-0.905**	-0.492
	(0.674)	(0.062)	(0.065)	(0.032)	(0.008)	(0.098)
Real WTI Price, yearly average (-7)	0.188**	0.0572*	0.0806***	-0.398	-0.770*	0.00326
	(0.001)	(0.018)	(0.000)	(0.053)	(0.025)	(0.981)
Real WTI Price, yearly average (-8)	0.213***	-0.0875*	0.113***	-0.467**	-0.329	-0.158
	(0.000)	(0.011)	(0.000)	(0.007)	(0.082)	(0.137)
Real WTI Price, yearly average (-9)	0.0601**	-0.0232	0.0998***	-0.0513	-0.227*	0.0542
	(0.001)	(0.282)	(0.000)	(0.605)	(0.010)	(0.381)
Constant	-0.0148***	0.00770***	-0.00198	-0.0870*	0.0933**	-0.00812
	(0.001)	(0.000)	(0.172)	(0.028)	(0.005)	(0.649)
Observations	165	165	165	109	109	109

Revenue targeting ←

→ **Competitive**

Competitive?

Revenue targeting

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Role of Prices: Country Level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OPEC		OECD			Non-OECD/non-OPEC	
	Saudi Arabia	United Arab Emirates	Norway	United Kingdom	United States	China	Russia
Real WTI price, monthly average (-1)	-0.0164	0.0213	-0.0816*	-0.203*	-0.0256	0.00619	0.0172
	(0.509)	(0.370)	(0.010)	(0.012)	(0.202)	(0.672)	(0.074)
Real WTI price, monthly average (-2)	0.0910***	0.0728*	-0.0626	-0.115**	-0.0603*	0.00750	0.0151**
	(0.000)	(0.034)	(0.458)	(0.008)	(0.025)	(0.563)	(0.006)
Real WTI price, quarterly average (-1)	-0.0634	0.0849	0.0482	-0.285**	-0.252**	0.0122	0.0330***
	(0.455)	(0.119)	(0.539)	(0.004)	(0.003)	(0.695)	(0.000)
Real WTI price, quarterly average (-2)	-0.0283	-0.0174	0.00923	0.249	-0.0403	0.00893	-0.0161**
	(0.648)	(0.663)	(0.889)	(0.098)	(0.442)	(0.642)	(0.006)
Real WTI price, quarterly average (-3)	0.0283	0.0228	-0.198***	-0.351***	-0.0161	0.0445*	0.000379
	(0.476)	(0.603)	(0.000)	(0.000)	(0.789)	(0.018)	(0.976)
Real WTI price, yearly average (-1)	-0.245	0.196	-0.991*	-0.895	0.380*	-0.00540	0.0989
	(0.066)	(0.250)	(0.017)	(0.081)	(0.040)	(0.946)	(0.094)
Real WTI price, yearly average (-2)	-0.376*	0.0807	-2.132***	-3.998***	0.185	0.161	0.246
	(0.034)	(0.842)	(0.000)	(0.000)	(0.478)	(0.108)	(0.068)
Real WTI price, yearly average (-3)	-0.119	1.327**	-2.413***	-5.018***	0.268	0.275	0.248
	(0.749)	(0.002)	(0.000)	(0.000)	(0.624)	(0.064)	(0.137)
Real WTI price, yearly average (-4)	-0.377	1.333*	-2.566***	-5.434***	-0.475	0.252	0.372*
	(0.263)	(0.012)	(0.001)	(0.001)	(0.434)	(0.128)	(0.021)
Real WTI price, yearly average (-5)	-0.324	2.107**	-3.003***	-4.942**	0.236	0.250	0.264
	(0.493)	(0.002)	(0.000)	(0.002)	(0.719)	(0.113)	(0.085)
Real WTI price, yearly average (-6)	-0.481	1.787*	-1.928**	-3.868**	-0.645	0.228	0.233*
	(0.249)	(0.012)	(0.001)	(0.007)	(0.219)	(0.141)	(0.017)
Real WTI price, yearly average (-7)	-0.345	1.777**	-1.064	-0.621	-0.219	0.0768	0.0734
	(0.426)	(0.005)	(0.225)	(0.592)	(0.633)	(0.548)	(0.086)
Real WTI price, yearly average (-8)	-0.388*	0.587	-1.356***	-0.334	0.178	0.0213	0.0634
	(0.022)	(0.135)	(0.000)	(0.445)	(0.181)	(0.691)	(0.096)
Real WTI price, yearly average (-9)	-0.155	0.405	-0.903***	-0.613*	0.0763	0.0203	0.00933
	(0.128)	(0.090)	(0.000)	(0.025)	(0.501)	(0.578)	(0.705)
Constant	-0.0727	0.212***	-0.0200	0.117**	0.108	0.0141**	-0.00626
	(0.138)	(0.001)	(0.756)	(0.005)	(0.086)	(0.007)	(0.074)
Observations	109	109	109	109	109	134	134
Share in group production							
Mean	33.2%	8.9%	13.4%	10.5%	39.8%	n/a	n/a
Min	30.5%	7.8%	10.3%	5.4%	34.9%	n/a	n/a
Max	36.7%	9.6%	15.4%	14.1%	44.2%	n/a	n/a

Like OPEC

Competitive behavior or different explanation?

OPEC like Saudi Arabia?

Less revenue smoothing

Competitive **Revenue smoothing**

Role of Global Real Economic Activity: Group Level

Counter-cyclical: consistent with OPEC stabilization objective

	All controls		
	(1)	(2)	(3)
	OPEC	OECD	non-OECD/ non-OPEC
Real BDI residuals, yearly average (-1)	-0.301	0.190***	-0.000325
	(0.151)	(0.000)	(0.990)
Real BDI residuals, yearly average (-2)	-0.320*	0.373***	-0.00655
	(0.038)	(0.000)	(0.868)
Real BDI residuals, yearly average (-3)	-0.436	0.596***	-0.0820
	(0.105)	(0.000)	(0.174)
Real BDI residuals, yearly average (-4)	-0.330***	0.446**	-0.0280
	(0.001)	(0.001)	(0.767)
Real BDI residuals, yearly average (-5)	-0.0300	0.273***	0.128
	(0.688)	(0.000)	(0.055)
Real BDI residuals, yearly average (-6)	-0.0654	0.216**	-0.0269
	(0.539)	(0.007)	(0.804)
Real BDI residuals, yearly average (-7)	0.0551	0.107	0.137
	(0.774)	(0.165)	(0.261)
Real BDI residuals, yearly average (-8)	-0.145	0.260**	0.268*
	(0.079)	(0.004)	(0.036)
Real BDI residuals, yearly average (-9)	-0.0144	0.277**	0.219*
	(0.818)	(0.004)	(0.017)
Constant	-0.0870*	0.0933**	-0.00812
	(0.028)	(0.005)	(0.649)
Observations	109	109	109

Pro-cyclical: consistent with competitive oil supply

Role of Global Real Economic Activity: Country Level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OPEC		OECD			Non-OECD/non-OPEC	
	Saudi Arabia	United Arab Emirates	Norway	United Kingdom	United States	China	Russia
Real BDI residuals, yearly average (-1)	-0.0495	0.589*	0.877***	0.967***	0.0658	0.0408	-0.0712
	(0.656)	(0.023)	(0.000)	(0.000)	(0.457)	(0.094)	(0.092)
Real BDI residuals, yearly average (-2)	-0.166	0.586	0.282	1.491***	0.0994	0.0481	-0.0789**
	(0.122)	(0.055)	(0.438)	(0.000)	(0.399)	(0.110)	(0.004)
Real BDI residuals, yearly average (-3)	-0.154	0.848**	0.355**	1.097***	0.526***	0.0461	-0.0988***
	(0.072)	(0.004)	(0.010)	(0.001)	(0.001)	(0.350)	(0.000)
Real BDI residuals, yearly average (-4)	-0.0801	-0.0275	0.208	1.577***	0.252	-0.0420	-0.155***
	(0.582)	(0.777)	(0.475)	(0.000)	(0.227)	(0.457)	(0.000)
Real BDI residuals, yearly average (-5)	-0.157***	-0.132	0.555*	0.881***	0.367**	-0.120***	-0.0987***
	(0.000)	(0.073)	(0.024)	(0.001)	(0.005)	(0.000)	(0.000)
Real BDI residuals, yearly average (-6)	-0.354	-0.0429	0.664**	0.692*	0.0985	0.0103	-0.0795**
	(0.155)	(0.779)	(0.001)	(0.031)	(0.438)	(0.821)	(0.007)
Real BDI residuals, yearly average (-7)	-0.113	0.439**	0.708	1.242***	-0.186	0.0844	-0.0474
	(0.706)	(0.005)	(0.051)	(0.000)	(0.259)	(0.120)	(0.233)
Real BDI residuals, yearly average (-8)	-0.0353	0.0439	0.490	1.973***	0.107	0.00426	0.00457
	(0.798)	(0.783)	(0.301)	(0.000)	(0.171)	(0.957)	(0.836)
Real BDI residuals, yearly average (-9)	0.135	-0.0166	-0.111	1.332***	0.341	-0.0138	-0.00190
	(0.159)	(0.867)	(0.712)	(0.000)	(0.094)	(0.864)	(0.915)
Constant	-0.0727	0.212***	-0.0200	0.117**	0.108	0.0141**	-0.00626
	(0.138)	(0.001)	(0.756)	(0.005)	(0.086)	(0.007)	(0.074)
Observations	109	109	109	109	109	134	134

Consistent with macro stabilization **Competitive** **Contradicts competitive behavior**

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Conclusions

- **Dynamic structure of our main model is important**
  - **We find significant responses across all lags**
    - **Static models may only capture part of the effect**
  - **In some cases the signs switch along the lag spectrum**
    - **Static models may be misleading since net effect may differ**
- **Substantial heterogeneity across both country groups and individual countries**
  - **Some countries resemble countries from other groups more than from their own groups**
- **Next steps:**
  - **Net output effects**
  - **SVAR**

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Thank you for your attention!

Contact: azaklan@diw.de

German Institute for Economic Research

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