Oil markets and global economic conditions: Evidence from a general equilibrium model

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Crude oil prices are volatile

(World Bank Pink Sheet, average over Brent, Dubai, and WTI prices, in USD)

What are the causes & consequence of oil price fluctuations?

- Key question for academics, practitioners, and policy makers
- Important repercussions on economic activity, firms, households, inflation dynamics, international trade, ...
- A large literature with SVAR models (e.g. Kilian, 2009; Kilian and Murphy, 2012, 2014; Baumeister and Peersman, 2013b,a; Baumeister and Hamilton, 2019; Juvenal and Petrella, 2015; Antolín-Díaz and Rubio-Ramírez, 2018; Caldara et al., 2019; Zhou, 2020; Cross et al., 2022; Braun, 2023,...)

No consensus on the sources of oil price fluctuations

Two main views in the SVAR literature:

- Kilian (2009) and Kilian and Murphy (2012, 2014): oil prices fluctuations mainly attributed to oil demand shocks; oil supply shocks do not matter (<10% of FEVD)
- Baumeister and Hamilton (2019) and Caldara et al. (2019): supply factors relatively more important (up to 37% of FEVD)

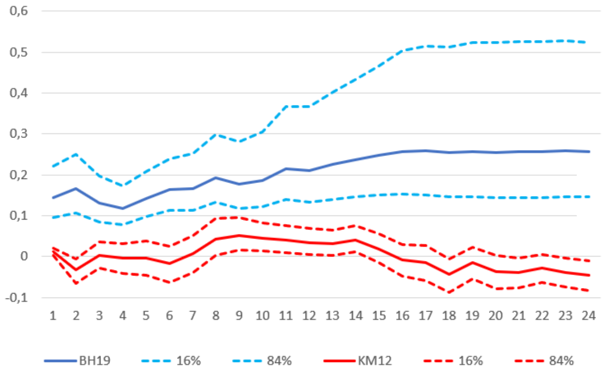
Disagreement due to different identification strategies

Herrera and Rangaraju (2020)

- Assumptions about the short-run elasticity of oil supply (σ_{sr})
- K09, KM12 and KM14: σ_{sr} bounded in the range (0-0.0258)
- BH19 and CCI19: σ_{sr} has a mode around (0.10-0.15)

Disagreement on the price-elasticity of oil supply in SVAR studies is not restricted to the short-run ...

Figure: Supply elasticities at different horizons, based on BH19: BH19 (blue) vs KM12 (red)



This paper

1. Build a simple RBC Model of the world oil market
   - Derive short- and long-term price-elasticities of oil supply as a function of a few structural parameters of the model
   - Accounting for the irreversibly and slow depreciation rate of oil investment controls this elasticity in the medium-run
2. The RBC model explains the SVAR disagreement: the medium and long-run elasticities matter too!
3. Estimate our model: oil supply shock more important when prior knowledge about the medium and long-run elasticities are accounted for.

RBC Model of the world oil market

Four blocks/shocks, inspired by SVAR in Kilian and Murphy (2014)

1. Oil supply
2. Oil consumption demand (price and income elasticities)
3. Oil inventory demand
4. Aggregate demand (e.g., King and Rebelo, 2000)

The model - oil supply

1. Exogenous discoveries of new land (L_t)
2. Drilling of new wells on land with capital (K_t)

$$\Lambda_t^{new} = \left[(1-\gamma)K_t^{\frac{\theta-1}{\theta}} + \gamma L_t^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \quad (1)$$

$$\Lambda_t = (1-\delta)\Lambda_{t-1} + \Lambda_{t-1}^{new} \quad (2)$$

3. Operating wells with labor

$$Y_t = \left[(1-\alpha)H_t^{\frac{\Theta-1}{\Theta}} + \alpha\Lambda_t^{\frac{\Theta-1}{\Theta}}\right]^{\frac{\Theta}{\Theta-1}} \quad (3)$$

Oil supply elasticity in the short and long runs

Short-run elasticity:

$$\sigma_{\text{sr}} = \frac{\Theta(1-\alpha)}{\alpha}$$

Long-run elasticity:

$$\sigma_{\text{lr}} = \sigma_{\text{sr}} + \frac{\theta(1-\gamma)}{\alpha\gamma}$$

Empirical strategy: calibrate the factor shares (α and γ); estimate σ_{lr} and σ_{lr}; get the CES parameters (Θ and θ) as by products

Calibration & priors - long-run elasticity

- Prior knowledge about the long-run elasticity of oil supply

Figure: Supply elasticities

	One year	Long-run
Bornstein et al. (2023, RES)	0.19	
Greene and Leiby (2006)		0.20-0.66
Fally and Sayre (2019)		0.29-0.60
Golombek et al. (2018, EE)		0.32
Rao (2018, AEJ:EP)		0.38
Bogmans (2024)	0.13	0.46

Calibration & priors - oil wells depreciation rate

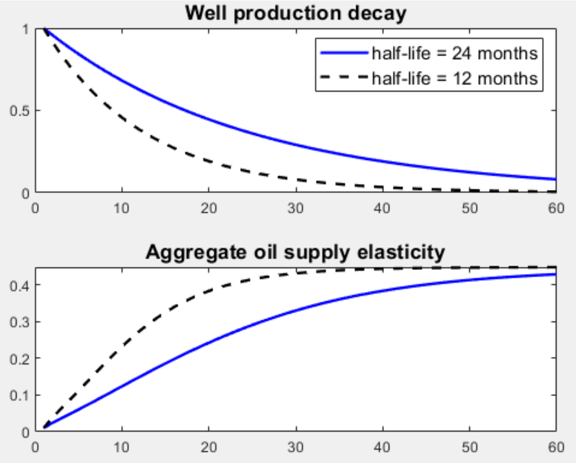
- Investment in oil wells is irreversible
- Production flows driven by physical constraints (declining pressure)

Figure: Speed of oil well production decay

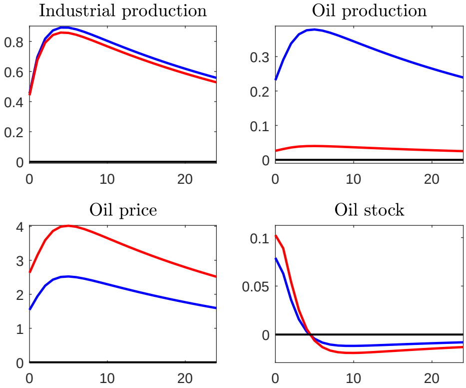
	Half production rate reached in
Wachtmeister et al. (2017, Nat. Resour. Res.)	less than 12 months
Kellogg (2014, AER)	7 months
Anderson et al. (2018, JPE)	6 to 24 months
Newell & Prest (2019, Energy J)	6 to 12 months

Adjustment speed towards the long-run elasticity

Half-life $= (1-\delta)/\delta$

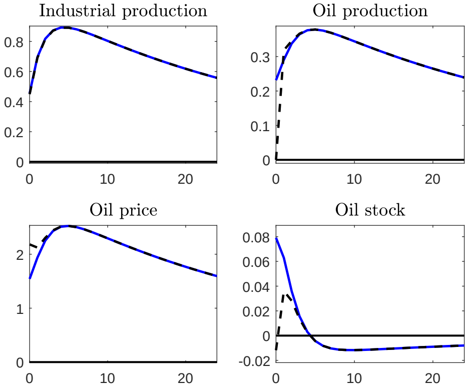


Varying the short and long-run price-elasticity of oil supply can explain the disagreement found in the SVAR literature



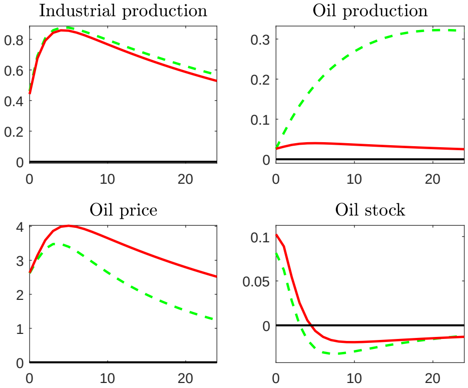
IRFs to an aggregate demand shock
Blue: BH19 case: $\sigma_{\text{sr}} = \sigma_{\text{lr}} = 0.15$
Red: KM14 case: $\sigma_{\text{sr}} = \sigma_{\text{lr}} = 0.01$

Varying the one-month price-elasticity of oil supply - in isolation - cannot explain the SVAR disagreement



IRFs to an aggregate demand shock
Blue: BH19 case: $\sigma_{sr} = \sigma_{lr} = 0.15$
Black: zero one-month elasticity of supply

Varying the long-run elasticity of supply contributes to explaining the SVAR disagreement



IRFs to an aggregate demand shock
Red: KM14 case: $\sigma_{sr} = \sigma_{lr} = 0.01$
Green: $\sigma_{sr} = 0.01$; $\sigma_{lr} = 0.45$

Revisit the question of the sources of oil price fluctuations

- Updated data from BH19 (1975-2019): oil prices (World Bank Pink Sheet, average over WTI, Brent, Dubai), oil production, oil inventories, world industrial production.
- Incorporate prior knowledge (literature) on the short and long-run elasticities of oil supply (and demand); as well as on the oil wells decay parameter
- The ability to incorporate priors on a long-run elasticity is an advantage of our framework

Benchmark inspired by KM12-KM14

- Bounded short-run elasticity ($\sigma_{sr} < 0.02$)
- (Almost) uninformative prior on the long-run elasticity

Table: Key parameters (KM-inspired benchmark estimates)

	Prior mean	Prior std	Post mode
$\sigma_{sr} \in [0, 0.02]$	0.01	0.005	0.02
σ_{lr}	0.45	0.39	0.05
δ	0.05	0.01	0.05
PEOD	0.20	0.10	0.35
IEOD	1.00	0.25	1.95

PEOD = price-elasticity of oil demand;
IEOD = income-elasticity of oil demand;

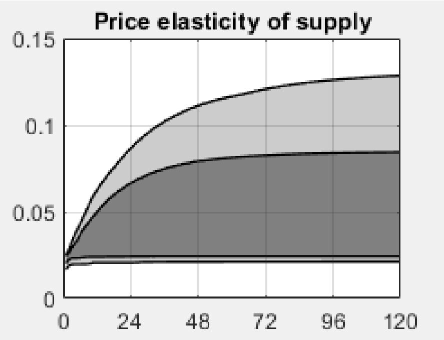
Demand shocks are the only important drivers of oil prices

Table: Variance decomposition (KM-inspired case)

	Oil supply	Aggregate Demand	Oil-consump Demand	Oil-invent Demand
Oil prod	89.95	3.66	6.03	0.00
IP	0.27	84.93	14.75	0.00
Oil price	6.77	29.86	60.68	0.02
68%	(4.82 ; 9.71)	(22.61 ; 41.86)	(50.73 ; 71.57)	(0.01 ; 0.04)
95%	(3.60 ; 12.70)	(16.61 ; 52.01)	(42.14 ; 76.51)	(0.01 ; 0.06)
Oil stock	4.37	5.65	14.12	75.30

But these results hinge upon a low long-run elasticity

- Long-run elasticity not within bounds of prior studies.



- Next step? bounded informative prior for σ_{lr}

Our baseline: bounded elasticities in the short and long-run

- Bounded short-run elasticity ($\sigma_{sr} < 0.02$)
- Informative prior on the long-run elasticity & decay parameters

Table: Priors and posteriors

	Prior mean	Prior std	Post mode
$\sigma_{sr} \in [0, 0.02]$	0.01	0.005	0.02
$\sigma_{lr} > 0.2$	0.45	0.13	0.27
δ	0.05	0.01	0.04
PEOD	0.20	0.10	0.36
IEOD	1.00	0.25	1.90

PEOD = price-elasticity of oil demand;
IEOD = income-elasticity of oil demand;

Smooth supply adjustment over time

- Short and long-run elasticities within bounds of prior studies.
- Transition from short to long-run elasticities half-way through in 2 years; almost complete in 5 years.

Demand shocks are the most important drivers of oil prices

But supply shocks play some role (FEVD between 9 and 26%), even when $\sigma_{sr} < 0.02$

Table: Variance decomposition (our baseline)

	Oil supply	Aggregate Demand	Oil-consump Demand	Oil-invent Demand
Oil prod	67.91	14.61	15.37	0.00
IP	0.70	88.39	10.59	0.00
Oil price	15.58	25.35	57.19	0.03
68%	(11.92 ; 21.04)	(20.51 ; 33.17)	(50.18 ; 63.75)	(0.02 ; 0.06)
95%	(9.38 ; 25.55)	(15.83 ; 42.48)	(39.74 ; 70.09)	(0.01 ; 0.10)
Oil stock	2.60	4.78	19.86	72.70

Conclusion and discussion

- Priors on the short-run and long-run elasticities of oil supply (and on the price and income elasticities of oil demand) in a general equilibrium model
- The SVAR literature focuses on the short-run price elasticity of oil supply, but the long-run elasticity is also important.
- Demand factors are the most likely dominant factors in explaining oil prices fluctuations, although supply shocks do play a non negligeable role - even when the one-month elasticity is close to zero.
- For future research: identification of metal/food supply shocks; effect of green transition on commodity prices...

Conclusion and discussion

- Thank you!
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The model - oil supply

Capture relevant features of the oil extraction industry

1. Exploration/permitting: endowment of land (oil fields)
2. Drilling new wells: up-front & irreversible capital investment
3. Operating wells requires labor and their productivity decays over time

Desirable features:

1. Gradual adjustment of oil supply to price changes due to the long-life of existing wells and gradual development of new wells
2. Closed-form solution for the the short and long-run elasticities of oil supply

Storage

Competitive risk-neutral storage firms maximize their expected profits of holding oil inventories $V_t(o)$:

$$\varepsilon_t^v(o)p_{t+1}(o)V_t(o) - p_t(o)V_t(o)\Phi(V_t(o)) \tag{4}$$

where $\Phi(V_t(o))$ captures a storage cost.

The linearized FOC of the storage firm is:

$$\hat{V}_t(o) = \varphi(o)\left\{\hat{p}_{t+1}(o) - \hat{p}_t(o) + \hat{\varepsilon}_t^v\right\} \tag{5}$$

- Depends positively on the expected price gain $\hat{p}_{t+1}(o) - \hat{p}_t(o)$
- Includes a speculation/precaution shock $\hat{\varepsilon}_t^v$

Oil demand

(1) firms combine labor and capital

$$VA_t(f) = \varepsilon_t(f) K_t(f)^{\alpha} H_t(f)^{1-\alpha}$$

(2) use oil using a modified CES production function:

$$Y_t(f) = \left[(1-\omega_o) \left(\frac{VA_t(f)}{VA(f)} \right)^{\frac{\eta_o - 1}{\eta_o}} + \omega_o \left(\frac{\varepsilon_t^{od}(O_t(f) - \bar{O})}{(O(f) - \bar{O})} \right)^{\frac{\eta_o - 1}{\eta_o}} \right]^{\frac{\eta_o}{\eta_o - 1}}$$

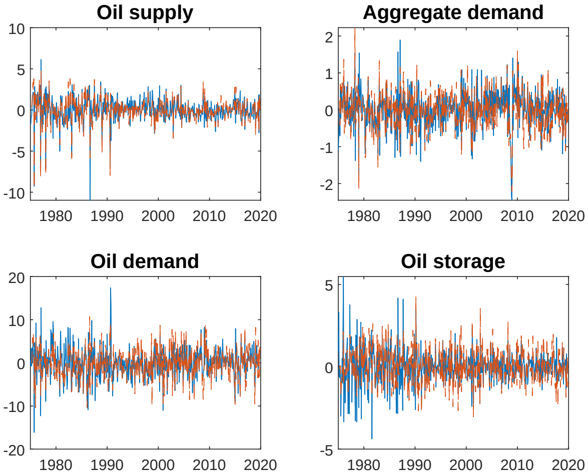
Linearized oil demand curve:

$$\hat{O}_t(f) = \delta_{\mathrm{y}} \hat{Y}_t(f) - \delta_{\mathrm{p}} \hat{p}_t(o) - \hat{\hat{\varepsilon}}_t^{od} \qquad (6)$$

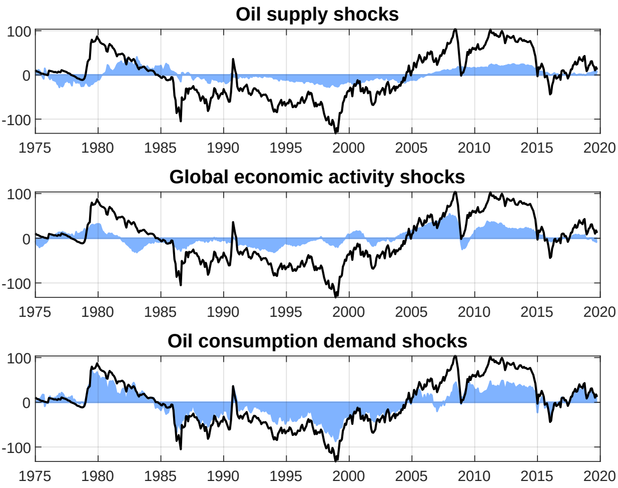
where $\delta_{\mathrm{y}} = \frac{O(f) - \bar{O}}{O(f)}$ is the output elasticity of oil demand and $\delta_{\mathrm{p}} = \eta_o \frac{O(f) - \bar{O}}{O(f)}$ is the price elasticity of oil demand.

Shocks in our model (blue) vs BH19 (red)

Correlation ranges from 0.85 (oil supply) to 0.63 (inventory demand)



Historical decomposition



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