Modeling Shocks in the Upstream Sector of the Oil and Gas Industry

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Motivation

Negative correlation between cash flows and lagged oil price: Where have all the profits gone?

Upstream sector is subject to increasing costs (Adelman, 1962). How steep is the supply curve? Is there heterogeneity? What determines the costs of drilling?

Understand the oil price (Pindyck, 1999; Hamilton, 2008; Kilian, 2009). What is the feedback from costs of drilling to the oil price?

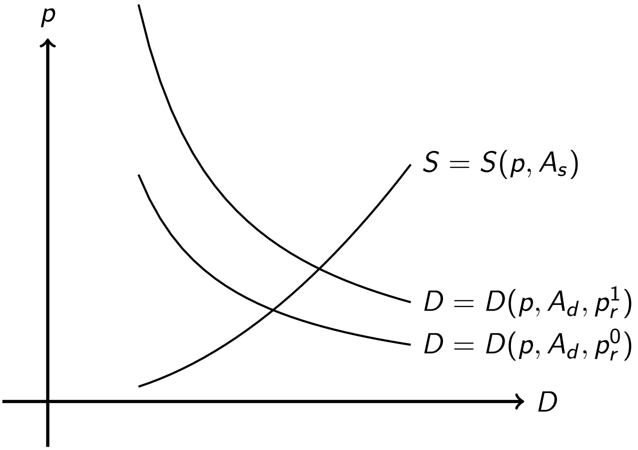
Contribution

We propose a structural model of the upstream sector in the oil and gas industry. ▸ Model

We use the real oil price and data on drilling activity and unit costs of drilling from Wood MacKenzie to identify three shocks. ▸ VAR

We estimate the dynamic effects of these shocks on activity, costs and the real price of oil.

Figure: Upstream sector in the oil and gas industry



Data

Data on exploration and appraisal wells between 1992 and 2012 for 25 major oil companies ▸ Details

Two quarterly variables:

1. Drilling activity: total number of exploration and appraisal wells drilled by a particular company (onshore/offshore).
2. Costs of drilling a meter: real variable costs in $US of drilling a meter and normalized by the depth of the well.

Results

1. A 1% increase in the oil price increases drilling activity by 1% and costs per meter drilled by 0.5%. Supply curve is steeper in countries with a lower GDP per capita.
2. The demand curve for drilling rigs in the upstream sector is flat.
3. Changes in costs of drilling do *not* significantly affect the price of crude oil permanently.

IRF

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Adelman, M. A. (1962). *The economics of petroleum supply: Papers by ma adelman, 1962-1993*. MIT press.

Hamilton, J. D. (2008). *Understanding crude oil prices* (Tech. Rep.). National Bureau of Economic Research.

Kellogg, R. (2011). Learning by drilling: Interfirm learning and relationship persistence in the texas oilpatch. *The Quarterly Journal of Economics*, *126*(4), 1961–2004.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *The American Economic Review*, 1053–1069.

Pindyck, R. S. (1999). The long-run evolution of energy prices.

Theoretical Framework

Aggregated Demand for Rigs:

$$\boldsymbol{D_d} = \left(\frac{p}{\alpha p_r A_d}\right)^{1/(\alpha-1)}$$

Aggregated Supply of Rigs:

$$\boldsymbol{D_s} = A_s^{1/1-\beta}\left(\frac{w}{p\beta}\right)^{\beta/(\beta-1)}$$

We equate changes in D to get a response to the shock:

$$\frac{\Delta \boldsymbol{D_d}}{\boldsymbol{D}} = -\xi\frac{\Delta p}{p} + \xi\frac{\Delta p_r}{p_r} + \xi\frac{\Delta A_d}{A_d} \qquad \xi = 1/(1-\alpha)$$

$$\frac{\Delta \boldsymbol{D_s}}{\boldsymbol{D}} = \theta\frac{\Delta p}{p} + \theta\beta^{-1}\frac{\Delta A_s}{A_s} \qquad \theta = \beta/(1-\beta)$$

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Estimation

$$\mathbf{A_0 Y_t} = \alpha + \sum_{\mathbf{i=1}}^{\mathbf{12}} \mathbf{A_i Y_{t-i}} + \varepsilon_{\mathbf{t}}$$

- $Y_t = (\Delta rop, \Delta drillings, \Delta cost)'$
- ϵ is a three dimensional vector with serially uncorrelated and mutually uncorrelated

Tests conducted: VAR stability, normality and serial correlation of errors and optimal number of lags.

In preferred specification we have 6 lags and use a dummy to control for the oil price shock in 2008q4.

Identification

$$\begin{pmatrix} e_t^{rop} \\ e_t^{drillings} \\ e_t^{cost} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} = 0 & a_{13} = 0 \\ a_{21} & a_{22} & a_{23} = 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \\ \varepsilon_t^3 \end{pmatrix}$$

We assume the oil price to be predetermined:

- it takes several year before production starts;
- it takes more than a year before estimates can be produced;

We assume supply to be predetermined to other demand shocks:

- supply constraints in the short run when exploring new regions.

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Collection of Data

1. meetings with energy companies, annual reports and industry specific publications;
2. state publications and information from public institutions;
3. historical data, investor presentations and different types of media sources.

Missing data: 23% on costs per meter is missing (assumed to be missing at random).

Transformation

Transformation of the data (Kilian, 2009):

1. Aggregating the data on location and company level: sum for drilling activity and mean for costs per meter drilled
2. We take the natural logarithm of the constructed time series and first difference the variables.
3. The individual series are weighted according to the number of wells drilled relative to the total number of wells drilled in the particular quarter and added up.

Figure: Growth of the main variable of interest ▸ Back

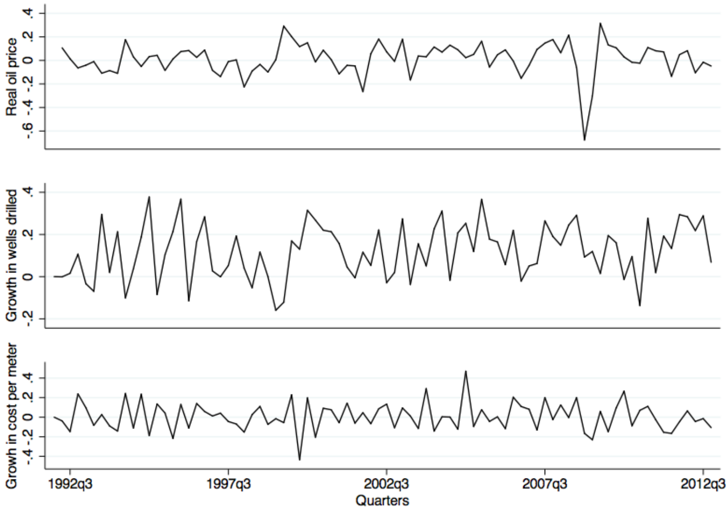

Figure: Responses to One-Standard-Deviation Structural Shocks ▸ Back