Business Cycles in an Oil Economy
Lessons from Norway

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* Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank.
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Research questions

(a) How important are ToT (oil) shocks for resource economies?
(b) What are the main transmission channels at play?
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Introduction

Agenda

What we do

- Estimate two-country DSGE model with endogenous oil price
- Quantify spillover and disentangle transmission channels
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Contributions to existing literature

- Alternative (complementary) identification approach
- Structural assessment of a range of shocks and transmission channels
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Main findings
- Propagation to oil rather than oil shocks are key
- Business cycles amplified by supply chains but dampened by fiscal regime (SWF and spending rule)
Related literature

- **Business cycles in open economies**

- **Oil and macro – DSGE**s
  - Bodenstein et al. (2011), Bodenstein and Guerrieri (2012), Kormilitsina (2011)
  - Nakov and Pescatori (2010a,b), Peersman and Stevens (2013), Pieschacon (2012)

- **Oil and macro – VARs**
  - Baumeister and Peersman (2013), Kilian and Murphy (2012), Kilian (2009)
A small VAR

The model:

\[ A_0 \tilde{y}_t = \sum_{j=1}^{J} A_j \tilde{y}_{t-j} + B \varepsilon_t, \quad \tilde{y}_t = [y_t^* \quad p_{o,t}^* \quad e_t \quad y_{o,t} \quad y_{m,t} \quad y_{s,t}]', \]

\[ \varepsilon_t \text{ iid } N(0, 1), \quad B \text{ diagonal} \]

Assumptions:

(i) Cholesky on international block \((A_{0,12} = 0)\)

(ii) Norway does not affect international economy \((A_0 \text{ and } A_j \text{ lower block triangular})\)

Spillover to Norwegian block freely estimated
Some stylized facts

International oil price shock

(a) Oil price

(b) International output

(c) Exchange rate

(d) Oil sector

(e) Manufacturing

(f) Services
Some stylized facts

International activity shock

(g) Oil price
(h) International output
(i) Exchange rate

(j) Oil sector
(k) Manufacturing
(l) Services
Lessons ("stylized facts")

Positive oil and activity shocks abroad are associated with
- Positive spillover to Mainland Norway
- Exchange rate *appreciates* after both shocks
- Stronger responses in oil than non-oil sectors
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Open questions:

- What are the underlying structural shocks?
- What are the main transmission channels?

⇒ Need a richer, structural model to analyze these questions
The model (Bergholt and Seneca, 2015)

- Two countries: SOE commodity exporter, ROW
- Manufacturing, service and oil industries in both countries
- Intersectoral network ⇒ international propagation of shocks
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- Core model
  - Wage/price rigidities, monopolistic competition
  - Habits and investment adjustment costs
  - LCP and incomplete exchange rate pass-through
  - Imperfect international risk sharing, premium associated with NFA position
The DSGE model

The model (Bergholt and Seneca, 2015)

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- SOE:
  - Oil sector and Mainland Norway
  - Mainland Norway linked to oil via supply chain
  - Fiscal policy: tax revenues, sovereign wealth fund, fiscal spending rule
  - Active monetary policy (Taylor rule)
A bird’s eye view
Oil extraction firms

- Discounted stream of cash flows

\[ \mathbb{E}_t \sum_{s=t}^{\infty} Z_{t,s} \left[ S_t P_{ro,t}^* O_t - P_{ro,t}^Y a(U_{o,t}) F_{O,t} - P_{ro,t}^Y I_{O,t} \right] \]

- Production technology

\[ O_t = Z_{O,t} Q_{O}^{1-\alpha_o} \bar{F}_{O,t}^{\alpha_o} \]

\[ \bar{F}_{O,t} = U_{O,t} F_{O,t} \] is active rigs and \( U_{O,t} \) is the utilization rate

- Rig investments

\[ F_{O,t+1} = (1 - \delta_o) F_{O,t} + Z_{F,t} \left[ 1 - \psi \left( \frac{I_{O,t}}{I_{O,t-1}} \right) \right] I_{O,t} \]
Oil extraction firms

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- Oil supply

- Short run utilization of existing rigs, long run investment in new rigs
- Entire expected oil price path matters rather than current price
- Breaks contemporaneous link between prices and activity
The domestic oil supply schedule

- Log-linearized optimality conditions:
  
  **Supply:** \( s_t + p_{ro,t}^* + o_t - u_{o,t} = rmc_{o,t} \)
  
  **Marginal cost:** \( rmc_{o,t} = p_{ro,t}^y + \gamma u_{o,t} + f_{o,t} \)
  
  **Production:** \( o_t = z_{o,t} + \alpha_o (u_{o,t} + f_{o,t}) \)

- Combining these, we get the supply schedule:

\[
o_t = \eta_o^s (s_t + p_{ro,t}^*) - \eta_o^s p_{ro,t}^y + \eta_o^s \gamma u f_{o,t} + \eta_o^s \frac{1 + \gamma u}{\alpha_o} z_{o,t}
\]

\[
\eta_o^s = \frac{\alpha_o}{1 + \gamma u - \alpha_o} \in [0, 1]
\] is the supply elasticity.
The DSGE model

Government

- Management of government’s oil revenues

  Tax revenues: \( TR^o_t = \tau_o \Pi_{o,t} \)

  GPFG: \( SWF_t = (1 - \rho_o) R^{*}_{t-1} \frac{\varepsilon_t}{\varepsilon_{t-1}} \Pi^{-1}_t SWF_{t-1} + TR^o_t \)

  Budget deficit: \( SBD_t = \rho_o R^{*}_{t-1} \frac{\varepsilon_t}{\varepsilon_{t-1}} \Pi^{-1}_t SWF_{t-1} \)

- Public budget: \( P^g_{r,t} G_t - D_t = T_t - R_{t-1} D_{t-1} \Pi^{-1}_t + SBD_t \)

- Public spending: \( G_t = G(“economic\ state_t”) \)

- Monetary policy: \( R_t = R(“economic\ state_t”) \)
Empirical analysis

Estimation

- **Data:** Norway and EU28, 2000Q1-2014Q4
  - Standard macro variables: manufacturing and services value added, aggregate private consumption, investment, wage and price inflation (y-on-y), interest rate, exchange rate
  - Oil variables: output, investments, Brent price

- **Estimation**
  - Bayesian inference: RWMH $\Rightarrow$ posterior distribution of parameters & macro moments
  - 18 observables, Kalman filter for remaining variables

- **Model fit:** reasonable for most variables, but ...
  - ... understates oil price volatility and persistence
  - ... overstates domestic consumption volatility and persistence
  - ... tension between oil price and oil investments
Empirical analysis

What drives the business cycle in Mainland Norway?

Note: Forecast error variance decomposition of GDP in Mainland Norway. Calculated at the posterior mean. Shocks are decomposed as follows: Domestic supply shocks (light blue), domestic demand shocks (dark blue), international supply shocks (light green), international demand shocks (dark green), and shocks in oil markets (light red). Numbers in white at the left and right hand side are decompositions at the 1 and 40 quarters horizons, respectively.

Bergholt and Larsen (Norges Bank)
Empirical analysis

Not all oil price “shocks” are alike

<table>
<thead>
<tr>
<th>Underlying international shock</th>
<th>Response of Mainland GDP</th>
<th>Mean</th>
<th>HPD interval</th>
<th># lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil supply</td>
<td></td>
<td>0.18</td>
<td>(0.13-0.25)</td>
<td>13</td>
</tr>
<tr>
<td>Manufacturing productivity</td>
<td></td>
<td>2.51</td>
<td>(0.98-3.82)</td>
<td>4</td>
</tr>
<tr>
<td>Service productivity</td>
<td></td>
<td>1.43</td>
<td>(−0.13-2.83)</td>
<td>7</td>
</tr>
<tr>
<td>Investment demand</td>
<td></td>
<td>1.46</td>
<td>(0.93-2.05)</td>
<td>8</td>
</tr>
<tr>
<td>Consumption demand</td>
<td></td>
<td>0.51</td>
<td>(0.39-0.63)</td>
<td>2</td>
</tr>
<tr>
<td>Labor market</td>
<td></td>
<td>1.94</td>
<td>(1.07-2.73)</td>
<td>7</td>
</tr>
<tr>
<td>Manufacturing markup</td>
<td></td>
<td>1.39</td>
<td>(0.12-2.65)</td>
<td>3</td>
</tr>
<tr>
<td>Service markup</td>
<td></td>
<td>1.20</td>
<td>(0.41-2.00)</td>
<td>6</td>
</tr>
<tr>
<td>Monetary policy</td>
<td></td>
<td>0.84</td>
<td>(0.50-1.20)</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: Posterior pass-through from oil price to Mainland GDP. Defined as the peak response of GDP when the oil price increases 10%, conditional on a given shock.
International oil supply shock

- GDP
- CONSUMPTION
- INVESTMENT
- REAL WAGE
- PRICE INFLATION
- INTEREST RATE
- GDP MANUFACTURING
- GDP SERVICES
- OIL PRICE

Bergholt and Larsen (Norges Bank)

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Impulse response analysis

Baseline model

Domestic spillover

Bergholt and Larsen (Norges Bank)

Business Cycles in an Oil Economy

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Counterfactual I: no feedback to world economy
Counterfactual II: no supply chain

The figure illustrates the impulse response analysis for various economic indicators under the scenario of no supply chain. The graphs show the response of GDP, consumption, investment, trade balance, real wage, price inflation, interest rate, exchange rate, GDP manufacturing, GDP services, GDP oil, and investment in the oil sector over a period of 20 periods. The y-axes are labeled with values ranging from -0.2 to 0.2 for most indicators, except for GDP and investment in the oil sector, which have different scales.

This analysis is based on the work of Bergholt and Larsen (Norges Bank) from the presentation on Business Cycles in an Oil Economy.
Counterfactual III: no sovereign wealth fund

Impulse response analysis

Counterfactuals

Bergholt and Larsen (Norges Bank)
Concluding remarks

What drives the business cycle in a prototype oil economy?

- Estimation of joint dynamics in oil markets, international economy, and Norway
  - Identification based on fully specified DSGE for international economy
  - Structural interpretation

Oil shocks not key, but amplification from oil response

Elasticities are shock dependent

External shocks are (i) amplified due to supply chain, but (ii) dampened due to fiscal regime (SWF and spending rule)

Left for future research

Depletion problem (Hotelling, 1931; Pindyck, 1978)

Policy implications (Catão and Chang, 2013; Hevia and Nicolini, 2013)

Financial frictions (Alberola and Chang, 2016; Hamann et al. 2016)
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