Commodity Prices and Sovereign Default: A New Perspective on the Harberger-Laursen-Metzler Effect

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ASSA Meetings, Philadelphia 2018
Introduction

- International oil price volatility has affected oil-exporter macro performance, through changes in incentives to
  - exploit a natural resource (real assets) affecting reserves and extraction of oil
  - consume and borrow/lend (financial assets)
  - incentives to repay or default, affecting sovereign risk and asset prices
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- Present a SOE sovereign risk model with incomplete international financial markets, in which optimal oil extraction and sovereign default interact, to help us understand these facts.
Average Ext. Public Debt of Net Oil Exporters (1979-2010)
Default Episodes (1979-2010)

Figure 2: Number of Default Episodes (1979-2010)
The Institutional Investor’s country credit ratings, are a sovereign debt risk index for the 1979-2010 period. It is published biannually in the March and September issues of Institutional Investor magazine. Those ratings are based on a survey of leading international bankers, who are asked to rate each country on a scale from 0 to 100 (where 100 represents maximum creditworthiness). The answers are then weighted in accordance with the particular bank’s global exposure and the level of sophistication for that country’s analysis systems.
## Empirical Results

<table>
<thead>
<tr>
<th></th>
<th>Model (1)</th>
<th>Model (2)</th>
<th>Model (3)</th>
</tr>
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<tbody>
<tr>
<td><strong>Convergence coefficient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inst. Investor Index (-1)</td>
<td>-0.248***</td>
<td>-0.199***</td>
<td>-0.248***</td>
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<tr>
<td></td>
<td>(0.0235)</td>
<td>(0.0231)</td>
<td>(0.0233)</td>
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<tr>
<td><strong>Short-run coefficients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>△ Oil GDP</td>
<td>0.0356**</td>
<td>0.0400**</td>
<td>0.0351**</td>
</tr>
<tr>
<td></td>
<td>(0.0160)</td>
<td>(0.0166)</td>
<td>(0.0159)</td>
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<tr>
<td>△ Non-oil GDP</td>
<td>0.389***</td>
<td>0.419***</td>
<td>0.377***</td>
</tr>
<tr>
<td></td>
<td>(0.0732)</td>
<td>(0.0755)</td>
<td>(0.0725)</td>
</tr>
<tr>
<td>△ Oil reserves</td>
<td>0.0429*</td>
<td>0.0488*</td>
<td>0.0515**</td>
</tr>
<tr>
<td></td>
<td>(0.0256)</td>
<td>(0.0267)</td>
<td>(0.0256)</td>
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<tr>
<td>△ Ext. pub. debt</td>
<td>-0.0611***</td>
<td>-0.0837***</td>
<td>-0.0628***</td>
</tr>
<tr>
<td></td>
<td>(0.0213)</td>
<td>(0.0239)</td>
<td>(0.0231)</td>
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<tr>
<td>△ NFA</td>
<td>-0.0326</td>
<td>-0.0326</td>
<td>-0.0282</td>
</tr>
<tr>
<td></td>
<td>(0.0326)</td>
<td>(0.0326)</td>
<td>(0.0312)</td>
</tr>
<tr>
<td><strong>Long-run coefficients</strong></td>
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<td></td>
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<td>0.0506</td>
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<td>0.0507</td>
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<tr>
<td></td>
<td>(0.0404)</td>
<td>(0.0513)</td>
<td>(0.0401)</td>
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<tr>
<td>Non-oil GDP</td>
<td>0.0632</td>
<td>0.158**</td>
<td>0.0771</td>
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<tr>
<td></td>
<td>(0.0537)</td>
<td>(0.0703)</td>
<td>(0.0536)</td>
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<tr>
<td>Oil reserves</td>
<td>-0.0855*</td>
<td>-0.100*</td>
<td>-0.121***</td>
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<tr>
<td></td>
<td>(0.0453)</td>
<td>(0.0596)</td>
<td>(0.0460)</td>
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<tr>
<td>Ext. pub. debt</td>
<td>-0.190***</td>
<td>-0.148***</td>
<td>-0.117***</td>
</tr>
<tr>
<td></td>
<td>(0.0347)</td>
<td>(0.0547)</td>
<td>(0.0424)</td>
</tr>
<tr>
<td>Default</td>
<td>-0.348***</td>
<td>-0.350***</td>
<td>-0.350***</td>
</tr>
<tr>
<td></td>
<td>(0.0526)</td>
<td>(0.0547)</td>
<td>(0.0526)</td>
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<tr>
<td>NFA</td>
<td>0.324***</td>
<td>0.242***</td>
<td>0.242***</td>
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<tr>
<td></td>
<td>(0.109)</td>
<td>(0.0821)</td>
<td>(0.0821)</td>
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<tr>
<td>Constant</td>
<td>0.767***</td>
<td>0.308</td>
<td>0.705***</td>
</tr>
<tr>
<td></td>
<td>(0.196)</td>
<td>(0.194)</td>
<td>(0.195)</td>
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<tr>
<td><strong>Observations</strong></td>
<td>512</td>
<td>509</td>
<td>509</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* *** p<0.01, ** p<0.05, * p<0.1
Summary of Evidence in Oil Exporting Countries

▶ In the short run, sovereign rating (measured by the Institutional Investor’s Index) is:
  ▶ negatively associated with an increase in external public debt
  ▶ positively associated with non-oil output growth
  ▶ positively associated with oil production growth
Summary of Evidence in Oil Exporting Countries

- In the short run, sovereign rating (measured by the Institutional Investor’s Index) is:
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- In the long run, sovereign rating is:
  - positively associated with oil and non-oil production
  - negatively associated with the size of the country’s oil reserves
  - negatively associated with the size of public debt (and defaults)
A Quantitative Model of Sovereign Default

- Small open economy with two types of goods:
  - tradable non-storable consumption good ($y_t$)
  - stock of oil ($s_t$) out of which $x_t$ units can be extracted

- Oil company
  - discovers oil at a fixed rate ($d$)
  - extracts it at a cost, $e = \psi\left(\frac{x}{s}\right)^\gamma$

- Sovereign government:
  - receives profits from oil company
  - issues debt but cannot commit to repay

- Relative price of oil ($p_t$) and consumption good are exogenous stochastic processes
Oil producing company problem

$$\max_{x_t,s_{t+1}} \mathbb{E}_t \sum_{t=1}^{\infty} Q_{t-1}(p_t x_t - e(s_t, x_t))$$

subject to

$$s_{t+1} = s_t - x_t + d,$$

(1)

$$0 \leq x_t \leq s_t + d,$$

(2)

where

$$Q_t = q(b_1, s_0, y_0, p_0) q(b_2, s_1, y_1, p_1) \ldots q(b_{t+1}, s_t, y_t, p_t),$$

and $$q(b_{t+1}, s_t, y_t, p_t)$$ is the realization of the stochastic discount factor in $$t$$.

- Optimal policies are $$x_t^*(p_t, s_t; b_{t+1})$$ and $$s_{t+1}^*(p_t, s_t; b_{t+1})$$ and optimal profits $$\pi_t^*$$ are transferred to the sovereign
Sovereign’s problem

The sovereign:

\[ V(b, s, y, p) = \max \left\{ v^{nd}(b, s, y, p), v^d(s, y, p) \right\}, \]

Repay:

\[ v^{nd}(b, s, y, p) = \max_{\{c, b'\}} \left\{ u(c) + \beta E \left[ V(b', s'^* (p, s; b'), y, p) \right] \right\} \]

\[ c - b = y + \pi^* (p, s; b') - q(b', s, y, p) b', \]
where

\[ \pi^* (p, s; b') = px^* (p, s; b') - e(s, x^* (p, s; b')). \]

Default:

\[ v^d(s, y, p) = \max_{\{c\}} \left\{ u(c) + \beta (1 - \lambda) Ev^d \left( s'^d, y, p \right) + \beta \lambda EV \left( 0, s'^* (p, s; 0), y', p' \right) \right\} \]

\[ c = \left[ 1 - \delta_0 \left( y + \pi^d (p, s) \right) \right] \left( y + \pi^d (p, s) \right). \]
The default set is given by

\[ D(b, s) = \left\{ \{y, p\} : \nu^{nd}(b, s, y, p) \leq \nu^d(s, y, p) \right\} \]

The probability of default at \( t + 1 \) perceived as of date \( t \) is given by

\[
d(b', s^\ast (b'; p, s), y, p) = \int \int_{D(b', s)} dz_y (y' | y) dz_p (p' | p)\]

The risk-neutral price of the sovereign bond is

\[
q(b'; s, y, p) = \bar{q} (1 - d(b'; s, y, p))
\]
Two-Period Model

- The firm chooses extraction in the first and second period, given a stock of oil, such that:

\[
\max_{x_1 \geq 0, x_2 \geq 0} p_1 x_1 - e(x_1, s_0) + q E_{p_2} [p_2 x_2 - e(x_2)]
\]

subject to

\[
s_0 = x_1 + x_2.
\]

- Let \( x_1^* (p_1, E(p_2), s_0; q(B_1)) \) and \( x_2^* (p_1, E(p_2), s_0; q(B_1)) \) be the optimal extraction policies.
Two-Period Model Continued

▶ The default decision (after $x_2^*$ is observed) is:

$$d = \begin{cases} 
1 & \text{if } u \left( \left[ 1 - \delta_0 (y_2 + \pi_2^*) \right] \pi_2^* \right) \geq u (y_2 + \pi_2^* + B_1) \\
0 & \text{otherwise}
\end{cases}$$

▶ Thus, given $B_1$, there is a $\tilde{p}_2$:

$$\tilde{p}_2 x_2^* (p_1, \tilde{p}_2, s_0; q) = \left(-\frac{B_1}{\delta_0}\right)^{\frac{1}{\delta_1+1}} - y_2$$

▶ The default probability is:

$$\delta (B_1, p_1, s_0) = \int_0^{\tilde{p}_2} d (B_1; p_1, p_2, s_0) h (p_2) dp_2.$$

▶ The optimal $B_1$ is:

$$\max_{B_1} u \left( y_1 + \pi_1^* - q (B_1, p_1, s_0) B_1 \right) + \beta \left\{ \delta (B_1, p_1, s_0) \int_0^{\tilde{p}_2(B_1, p_1, s_0)} u \left( \left[ 1 - \delta_0 (y_2 + \pi_2^*) \right] \pi_2^* \right) h (p_2) dp_2 \\
+ [1 - \delta (B_1, p_1, s_0)] \int_{\tilde{p}_2(B_1, p_1, s_0)}^{\infty} u (y_2 + \pi_2^* + B_1) h (p_2) dp_2 \right\}.$$
Optimal Extraction Policies

Optimal extraction policy $x_1^*$, with $q = 0.85$

Optimal extraction policy $x_2^*$, with $q = 0.85$

Oil price $P_1$  Oil price $P_2$  Oil price $P_2$  Oil price $P_1$
Comparative Statics

1. For Debt $B_1$:
   - As debt increases, the bond price $q$ increases.
   - The relationship is approximately linear.

2. For Oil reserves $S_0$:
   - As oil reserves increase, the bond price $q$ decreases.
   - The relationship is approximately linear.

3. For Relative price of oil $P_1$:
   - As the relative price of oil increases, the bond price $q$ decreases.
   - The relationship is approximately linear.

4. For Relative price of oil $P_2$:
   - As the relative price of oil increases, the bond price $q$ increases.
   - The relationship is approximately linear.
Calibration to Russia

- Russia National Accounts - Haver/OECD (2003Q1-2015Q4)
- Risk premium: JP Morgan’s EMBI+ GSS spread for the period 1997Q4-2017Q1
- Default episodes and debt: Reinhart and Rogoff, AER (annual, 1800-2010) Total (public plus private) gross external Debt/GNP ratio is 40% (avg1992-2010)
- Financial exclusion: Richmond and Dias (2009)
### Parametrization

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<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<td>$\mu$</td>
<td>risk aversion</td>
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<tr>
<td>$\bar{q}$</td>
<td>risk-free bond price</td>
<td>0.99</td>
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<tr>
<td>$d$</td>
<td>discovery rate</td>
<td>0.1</td>
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<tr>
<td>$\beta$</td>
<td>discount factor</td>
<td>0.794</td>
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<td>$\delta_0$</td>
<td>level parameter of default cost</td>
<td>0.045</td>
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<td>$\delta_1$</td>
<td>curvature parameter of default cost</td>
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<tr>
<td>$\lambda$</td>
<td>probability of re-entry</td>
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<tr>
<td>$\phi$</td>
<td>level parameter of extraction cost</td>
<td>4.86</td>
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<tr>
<td>$\gamma$</td>
<td>curvature parameter of extraction cost</td>
<td>0.472</td>
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### Matching Moments

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<tr>
<th>Description</th>
<th>Target</th>
<th>Model</th>
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<tbody>
<tr>
<td>Average reserves (in years)</td>
<td>18.4</td>
<td>19.6</td>
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<tr>
<td>Std dev of oil extraction (pct)</td>
<td>4.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Default rate (pct)</td>
<td>2.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Average external Debt to GDP (pct)</td>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>Average EMBI spread (bp)</td>
<td>674</td>
<td>1199</td>
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<tr>
<td>Std dev of bond price (pct)</td>
<td>7.4</td>
<td>19.3</td>
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Can the model explain our empirical findings?

<table>
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<th>Average</th>
<th>Unconditional</th>
<th>Under Default</th>
<th>Under Repayment</th>
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<tbody>
<tr>
<td>Oil prices</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Non-oil output</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Oil reserves</td>
<td>6.16</td>
<td>6.43</td>
<td>6.10</td>
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<tr>
<td>Oil extraction</td>
<td>0.1</td>
<td>0.08</td>
<td>0.11</td>
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<tr>
<td>GDP</td>
<td>1</td>
<td>0.9</td>
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<tr>
<td>External debt (pct)</td>
<td>27</td>
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<tr>
<td>Sovereign debt price</td>
<td>0.71</td>
<td>0</td>
<td>0.85</td>
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</table>
Dynamics around default episodes

[Graphs showing oil price, oil reserves, extraction, debt, consumption, debt price, and CA over different time periods (t-4 to t+4).]
Final Remarks

- Document empirically how sovereign risk relates to oil ownership

- Model of natural resource extraction and sovereign risk that captures
  - larger oil reserves are associated with higher sovereign risk
  - more oil extraction is associated with lower sovereign risk
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  - larger oil reserves are associated with higher sovereign risk
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- Work in progress:
  - changes in the discovery rate
  - does oil ownership matter?
Data

- Total public debt to GDP: World Development Indicators tables (WDI) and World Economic Outlook database (WEO). Annual data from 1979 to 2010.