The Causal Relationship in North American Energy Production

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Introduction

- Significant changes have occurred in North American energy markets over the past decade
  - Particularly in the case of the United States → Shale revolution

- Since 2002, the US has seen a 12-fold increase in the production of natural gas from shale

- In 2013 US production of shale oil (3.5 mb/d) was 3 times higher than 2010.

- Four decade oil ban on oil exports recently overturned In US
US Primary Energy Production

Note: The data was obtained from the Federal Reserve Economic Database, and is Industrial Production: Mining: Crude oil and Industrial Production: Mining: Natural gas.
Canadian Impact?

What is the nature of the impact on the Canadian market?

- Similar geologic formation of comparable composition.
  - Bakken on the Border

- Spread of new techniques / technology

- Vast majority of energy commodities are exported to the US
  - US market now flush with crude oil and natural gas

- Hughes (2013) discusses the high decline rates in shale wells
North American Energy Production

CRUDE OIL

Natural Gas

US

Canada
Econometric Methodology

• Simple Model

\[ OP_{l,t} = \alpha_0 + \alpha_1 OP_{l,t-1} + \alpha_2 OP_{k,t-1} + e_{1,t} \]

\[ GP_{l,t} = \beta_0 + \beta_1 GP_{l,t-1} + \beta_2 GP_{k,t-1} + e_{2,t} \]

• Complete Model

\[ OP_{l,t} = \alpha_0 + \alpha_1 OP_{l,t-1} + \alpha_2 OP_{k,t-1} + \alpha_3 WTIP_t + \alpha_4 FX_t + e_{1,t} \]

\[ GP_{l,t} = \beta_0 + \beta_1 GP_{l,t-1} + \beta_2 GP_{k,t-1} + \beta_3 HHP_t + \beta_4 Storage + \beta_5 CDD_t + \beta_6 HDD_t + e_{2,t} \]
Data

- Monthly production data; 2002 through early 2015

<table>
<thead>
<tr>
<th>Table: Summary Statistics</th>
<th>Natural Gas</th>
<th>Crude Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.A.</td>
<td>CDA</td>
</tr>
<tr>
<td><strong>Beginning</strong></td>
<td>September-02</td>
<td>September-02</td>
</tr>
<tr>
<td><strong>End</strong></td>
<td>August-15</td>
<td>August-15</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>50.62</td>
<td>14.45</td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>44.30</td>
<td>1.97</td>
</tr>
<tr>
<td><strong>STd. Dev</strong></td>
<td>6.66</td>
<td>1.41</td>
</tr>
<tr>
<td><strong>Coefficient of Variation</strong></td>
<td>13.1%</td>
<td>9.7%</td>
</tr>
<tr>
<td><strong>Skew</strong></td>
<td>0.57</td>
<td>-0.31</td>
</tr>
<tr>
<td><strong>Kurt</strong></td>
<td>-0.66</td>
<td>-0.92</td>
</tr>
<tr>
<td><strong>JB Test Normality</strong></td>
<td>11.19</td>
<td>8.01</td>
</tr>
<tr>
<td><strong>p - value</strong></td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>156</td>
<td>156</td>
</tr>
</tbody>
</table>
Results

• Augmented Dickey – Fuller Test
  • US and Canadian crude oil and natural gas production is nonstationary in levels
  • All series are stationary in first differences

• Cointegration tests
  • Johansen Test indicates cointegrating relationship for crude oil
  • Less clear for Natural Gas
  • Park test supportive of cointegration
Vector Error correction model

• Results:
  • Speed of adjustment term is significant across models
  • Consistently higher for Canadian production than for American production
  • Coefficient is positive in the final two natural gas models.
Natural Gas Production
### Granger Causality Tests

<table>
<thead>
<tr>
<th>#</th>
<th>Model</th>
<th>$\chi^2$ stat</th>
<th>p-value</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$OP_{US} = f(OP_{CDA})$</td>
<td>30.502</td>
<td>0.000</td>
<td>Bi-directional</td>
</tr>
<tr>
<td>2</td>
<td>$OP_{CDA} = f(OP_{US})$</td>
<td>52.991</td>
<td>0.000</td>
<td>Bi-directional</td>
</tr>
<tr>
<td>3</td>
<td>$OP_{US} = f(OP_{CDA}, WTIP, FX)$</td>
<td>50.343</td>
<td>0.000</td>
<td>Bi-directional</td>
</tr>
<tr>
<td>4</td>
<td>$OP_{CDA} = f(OP_{US}, WTIP, FX)$</td>
<td>18.005</td>
<td>0.000</td>
<td>Bi-directional</td>
</tr>
<tr>
<td>5</td>
<td>$GP_{US} = f(GP_{CDA})$</td>
<td>7.153</td>
<td>0.007</td>
<td>USA $\rightarrow$</td>
</tr>
<tr>
<td>6</td>
<td>$GP_{CDA} = f(GP_{US})$</td>
<td>0.541</td>
<td>0.462</td>
<td>Canada</td>
</tr>
<tr>
<td>7</td>
<td>$GP_{US} = f(GP_{CDA}, Storage, HDD, CDD)$</td>
<td>13.031</td>
<td>0.001</td>
<td>USA $\rightarrow$</td>
</tr>
<tr>
<td>8</td>
<td>$GP_{CDA} = f(GP_{US}, Storage, HDD, CDD)$</td>
<td>2.766</td>
<td>0.251</td>
<td>Canada</td>
</tr>
</tbody>
</table>

Note: $\chi^2$ represents the test statistic in the Granger Causality test.
Implications & Conclusions

• Park’s CCR results support the notion that the production variables are cointegrated.

• Granger Causality tests with the CCR terms included provide same results as above except
  • Presence of bi-directional causal relationship in production of natural gas (simple model)

• North American is a highly integrated energy market
  • Long-run relationship among crude oil and natural gas production