Impact of U.S. Shale Gas and Corn Markets on Ammonia Prices

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Motivation

- **Cost forecast:** Procurement & Supply chain management is focused on understanding cost drivers and forecasting cost inputs for Chevron

- Traditional should cost model focuses on cost breakdown whereas approach used here allows consideration of factors from demand side and policy on cost

- Key goal is to understand ammonia prices drivers and forecast ammonia prices

- **Upstream Production Chemicals:**
  - Ammonia is a key input in production chemicals uses directly or as a compound or derivative chemical:
    - Direct Compounds: Ammonium Sulfate (breaker/viscosity reducer), Ammonium Bisulfate (corrosion inhibitor), Ammonium Chloride (iron control)
    - Amides: 2-Dibromo-3-Nitrilopropionamide

- **Production process:**
  - Industrial ammonia is produced from natural gas which accounts for over 75% of the cost of production of ammonia
Literature Review

Structural shifts & market changes
New Pricing Paradigms

- Advent of shale gas:
  - Surge in US supply post-2008 when the ammonia-gas relationship started weakening
  - Growth of stranded gas monetization projects in Trinidad, Equatorial Guinea and Middle East and return of US ammonia mothballed supply as well as new projects

- US Ethanol Mandates:
  - Post-2007 legislative mandate making ethanol the chosen blend in the gasoline pool to replace Methyl Tertiary Butyl Ether (MTBE).
  - The push for compliance with this new mandate led to soaring demand for corn which is the largest feedstock source for producing ethanol.
  - Farmers’ preference for corn as their leading crop choice, demanded higher volumes of ammonia since it is the most effective nitrogen source.
New source of nitrogen/ammonia demand
Corn demand jumps post-ethanol mandates

- **Pre-2007**: Feed market dominates corn use
Methodology

- Vector Autoregression:
  - Tested the relationship of corn prices (No. 2 Chicago), Ammonia (Tampa CFR) and Natural Gas (Henry Hub)
  - Granger Causality test showed corn prices granger cause ammonia prices
  - Build VAR model to obtain significant coefficients
  - Test Impulse Response Functions
  - Results
Methodology

- **Vector Autoregression:**
  - Tested the relationship of corn prices (No. 2 Chicago), Ammonia (Tampa CFR) and Natural Gas (Henry Hub)
  - Granger Causality test showed corn prices granger cause ammonia prices

Pairwise Granger Causality Tests
Date: 09/05/13   Time: 21:48
Sample: 2000M01 2016M12
Lags: 2

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Obs</th>
<th>F-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>LOGCORN does not Granger Cause LOGAMMONIAT</td>
<td>162</td>
<td>9.51049</td>
<td>0.0001</td>
</tr>
<tr>
<td>LOGAMMONIAT does not Granger Cause LOGCORN</td>
<td></td>
<td>0.80552</td>
<td>0.4487</td>
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</table>
**Methodology**

**Vector Autoregression:**

- **Build VAR Model:**

<table>
<thead>
<tr>
<th></th>
<th>LOGAMMONIAT</th>
<th>LOGCORN</th>
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<tbody>
<tr>
<td>LOGAMMONIAT(-1)</td>
<td>1.365853</td>
<td>0.035812</td>
</tr>
<tr>
<td></td>
<td>(0.06720)</td>
<td>(0.04094)</td>
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<td></td>
<td>[20.3246]</td>
<td>[0.87473]</td>
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<tr>
<td>LOGAMMONIAT(-2)</td>
<td>-0.534601</td>
<td>-0.014625</td>
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<tr>
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<td>(0.06607)</td>
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<td>[-8.09184]</td>
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<tr>
<td>LOGCORN(-1)</td>
<td>0.150479</td>
<td>1.300788</td>
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<tr>
<td></td>
<td>(0.12447)</td>
<td>(0.07583)</td>
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<td>[1.20892]</td>
<td>[17.1536]</td>
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<tr>
<td>LOGCORN(-2)</td>
<td>-0.008872</td>
<td>-0.334572</td>
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<tr>
<td></td>
<td>(0.12654)</td>
<td>(0.07709)</td>
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<tr>
<td></td>
<td>[-0.07011]</td>
<td>[-4.33987]</td>
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<tr>
<td>C</td>
<td>0.805280</td>
<td>-0.078329</td>
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<tr>
<td></td>
<td>(0.14891)</td>
<td>(0.09072)</td>
</tr>
<tr>
<td></td>
<td>[5.40784]</td>
<td>[-0.86343]</td>
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</table>

**Statistics:**

- **R-squared:** 0.947058
- **Adj. R-squared:** 0.945709
- **Sum sq. resid:** 2.325747
- **S.E. equation:** 0.127111
- **F-statistic:** 702.1250
- **Log likelihood:** -1.343950
- **Mean dependent:** 5.727807
- **S.D. dependent:** 0.522357

**Additional Statistics:**

- **Determinant resid covariance (dof adj.):** 8.13E-05
- **Determinant resid covariance:** 7.64E-05
- **Log likelihood:** 308.1208
- **Akaike information criterion:** -3.680504
- **Schwarz criterion:** -3.489912
Methodology

- Vector Autoregression:
  - Lag order selection
  - View Impulse Response Functions:
    - Ammonia prices are impacted by corn prices (significant impact happens after 4 periods)
Methodology

- Vector Autoregression:
  - Estimate equation system to ensure significant coefficients to arrive at final model

System: SYS01
Estimation Method: Seemingly Unrelated Regression
Date: 09/05/13   Time: 22:09
Sample: 2000M03 2013M08
Included observations: 162
Total system (balanced) observations 324
Linear estimation after one-step weighting matrix

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
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Determinant residual covariance 7.82E-05

Equation: LOGAMMONIAT = C(1)*LOGAMMONIAT(-1) + C(2)*LOGAMMONIAT(-2) + C(3)*LOGCORN(-1) + C(5)
Observations: 162
R-squared 0.947054  Mean dependent var 5.727808
Adjusted R-squared 0.946049  S.D. dependent var 0.522357
S.E. of regression 0.121330  Sum squared resid 2.325897
Durbin-Watson stat 1.483472

Equation: LOGCORN = C(8)*LOGCORN(-1) + C(9)*LOGCORN(-2)
Observations: 162
R-squared 0.977251  Mean dependent var 1.157585
Adjusted R-squared 0.977108  S.D. dependent var 0.491287
S.E. of regression 0.074331  Sum squared resid 0.884026
Durbin-Watson stat 1.992280
Results

- Testing the ammonia forecast both in-sample and out of sample
- Forecast performance: Ex-post analysis shows that the forecast is within 10% of actual values Vs. existing models based on gas prices which are much higher
- Future work:
  - Improve forecast accuracy further by including other nitrogen sources
  - Understand lag between ammonia price changes to Chevron supply chain cost impact
**Implications**

- **Cost forecasting:** Increased accuracy forecast helps Chevron plan for supply chain costs, risks and contingencies.

- **Policy Evaluation:**
  - From a policy perspective, ethanol mandates have caused a shift in crop choice and consequences for farm economics, acreage and crop pricing.
  - Corn prices in turn have reset relationships for chemical fertilizer prices which we can now better understand.
  - Supply chain impacts of major commodity chemicals such as ammonia used in multiple industries (oil & gas, mining, resins, chemicals) can now be better understood.