Foreign Price Risk and Homogeneous Commodity Imports: A Focus on Soybean Demand in China

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December 11-13, 2011
St. Petersburg, Florida

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Overview

- This study provides a theoretical foundation and model that relates import price risk to the allocation of a homogeneous commodity across exporting countries.

- A differential approach to expected utility theory and firm demand is used to derive an empirical model that accounts for the effects of price risk on the demand for a commodity disaggregated by source.

- My focus is the soybean market in China, which is the largest destination market for global soybean exports.
Why is price risk important?

- In purchasing a commodity from multiple countries, firms are diversifying away the price risk associated with relying on a single low-cost exporter.

- Dudley (1983) - when input prices are uncertain, it is generally optimal for a firm to remain diversified in its choice of suppliers even when prices differ across sources.

- Wolak and Kolstad (1991) - import allocation is analogous to asset allocation where risk management behavior could explain why a homogeneous commodity is sourced from multiple countries.
Past Research...


- **Import allocation and price risk:** Wolak and Kolstad (1991) (Japanese steam-coal imports), and Seo (2001) (Chinese wheat imports).
(billion kilograms)

Source: World Trade Atlas Database
($US per kilograms)

Source: World Trade Atlas Database
(log differences)

Source: World Trade Atlas Database
Import allocation as the first stage of an expected utility problem...

\[ R : \text{net revenue from outputs and domestic resources.} \]
\[ p_i \text{ and } q_i \text{ denote the price and quantity of a commodity from the } i\text{th country} \]
\( (i = 1, 2 \ldots n). \)

The optimal allocation of \( q \) is the solution to the following:

\[
\begin{align*}
\text{Max } & \quad U_q \left[ R - E(p'q), V(p'q) \right] \\
\text{s.t. } & \quad Q = v'q, \quad q \geq 0
\end{align*}
\]

The Lagrangian for the utility maximization problem is

\[
\Lambda = U(R - \tilde{p}'q, q'\Omega q) + \lambda(Q - v'q)
\]

The first order condition with respect to the \( i\)th import \( (q_i) \) is

\[
\Lambda_i = \frac{\partial \Lambda}{\partial q_i} = -U_1 p_i + 2U_2 \left( q_i \sigma_i^2 + \sum_{j \neq i} q_j \sigma_{ij} \right) - \lambda = 0
\]
Import allocation equation in general form...

The optimization problem results in a system of import demand equations...

\[ q_i^* = q_i(Q, \tilde{p}_1, \tilde{p}_2, \ldots, \tilde{p}_n, \sigma_{1}^2, \sigma_{2}^2, \ldots, \sigma_{n}^2) \]

Similar to the differential approach (Theil, 1977; Theil, 1980; Laitinen, 1980; Theil and Clements, 1987)…

\[ dq_i = \frac{\partial q_i}{\partial Q} dQ + \sum_{j=1}^{n} \frac{\partial q_i}{\partial \tilde{p}_j} d\tilde{p}_j + \sum_{j=1}^{n} \frac{\partial q_i}{\partial \sigma_j^2} d\sigma_j^2 \]

With some manipulation…

\[ s_i d \log q_i = \frac{\partial q_i}{\partial Q} d \log Q + s_i \sum_{j=1}^{n} \frac{\partial \log q_i}{\partial \log \tilde{p}_j} d \log \tilde{p}_j + s_i \sum_{j=1}^{n} \frac{\partial \log q_i}{\partial \log \sigma_j^2} d \log \sigma_j^2 \]

\[ s_i = q_i/Q \] is the share of imports from country \( i \) in total imports.
Solving for the price and variance effects…

\[ s_i d \log q_i = \frac{\partial q_i}{\partial Q} d \log Q + s_i \sum_{j=1}^{n} \frac{\partial \log q_i}{\partial \log \tilde{p}_j} d \log \tilde{p}_j + s_i \sum_{j=1}^{n} \frac{\partial \log q_i}{\partial \log Q} \frac{\partial \log \sigma^2_j}{\partial \log \sigma^2_j} d \log \sigma^2_j \]

\[ \frac{\partial \log q_i}{\partial \log p_j} = u^{ij} \gamma_j - E_j \sum_{j=1}^{n} u^{ij} \psi_{1j} + \frac{\partial \log q_i}{\partial \log Q} \frac{\partial \log Q}{\partial \log \lambda} \frac{\partial \log \lambda}{\partial \log p_j} \]

\[ \frac{\partial \log q_i}{\partial \log \sigma^2_j} = -u^{ij} \phi_{jj} - V_j \sum_{j=1}^{n} u^{ij} \psi_{2j} + \frac{\partial \log q_i}{\partial \log Q} \frac{\partial \log Q}{\partial \log \lambda} \frac{\partial \log \lambda}{\partial \log \sigma^2_j} \]
Differential Import Allocation (DIA) Model

\[
\bar{s}_{it} \Delta q_{it} = \theta_i \Delta Q_t^* + \sum_{j=1}^{n} \pi_{ij} \Delta \bar{p}_{jt} + \sum_{j=1}^{n} \nu_{ij} \Delta \sigma_{jt}^2 + \sum_{m=1}^{12} \delta_i d_m + \epsilon_{it}
\]

\[\Delta x_t = \ln(x_t) - \ln(x_{t-1}) \approx d \log x_t\]

\[\bar{s}_{it} = 0.5(s_{it} + s_{it-1})\]

\[\Delta Q_t^* = \sum_{i=1}^{n} \bar{s}_{it} \Delta q_{it}\]

\[\theta_i = \partial q_i / \partial Q\]

The **DIA model** is similar to the **Rotterdam model** with exception of the following:

- The average and marginal share \((s_i\) and \(\theta_i\)) are defined in terms of quantity and not expenditures.
- Allocation is based on the aggregate quantity and not aggregate expenditures;
- Import demand is determined by price expectations and risk, and not actual prices.
Differential Import Allocation (DIA) Model

\[ \Delta q_{it} = \theta_i \Delta Q_t^* + \sum_{j=1}^{n} \pi_{ij} \Delta \tilde{p}_{jt} + \sum_{j=1}^{n} \nu_{ij} \Delta \sigma_{jt}^2 + \sum_{m=1}^{12} \delta_i d_m + \varepsilon_{it} \]

Adding up (constraint condition): \[ \sum_{i=1}^{n} \theta_i = 1; \sum_{i=1}^{n} \pi_{ij} = 0; \sum_{i=1}^{n} \nu_{ij} = 0; \sum_{i=1}^{n} \delta_i = 0 \]

Negativity: \[ \pi_{ii} < 0 \forall i \]

Risk adverse: \[ \nu_{ii} < 0 \forall i \]

Homogeneity: \[ \sum_{j=1}^{n} \pi_{ij} = 0 \]

Symmetry: \[ \pi_{ij} = \pi_{ji} \]

Risk Neutrality: \[ \nu_{ij} = 0 \forall ij \]
Soybean Imports in China

- China is the largest soybean importing country in the world. According to the United Nations, global soybean trade is valued at $28.1 billion (2009), where China accounts for about two-thirds of this total.

- China is also a large soybean-producing country. Domestic soybeans are non-biotech and primarily used to produce food products. Imported soybeans are categorized as biotech and can only be used to produce soybean meal and oil.


- During this period, Argentina, Brazil, the United States accounted for about 99% of total soybean imports and separately accounted for 21.1%, 33.3%, and 44.2%, respectively, on average.
Multivariate ARCH Procedure

To obtain the conditional expectation and variance of import prices, the following autoregressive equation is estimated assuming a Multivariate ARCH(2) process.

\[ \Delta p_t = \alpha_0 + A_1 \Delta p_{t-1} + A_2 \Delta z_t + A_3 \Delta z_{t-1} + \varepsilon_t \]

\[ \hat{\Omega}_t = B_0 + B_1 \varepsilon_{t-1} \varepsilon'_{t-1} B_1 + B_2 \varepsilon_{t-2} \varepsilon'_{t-2} B_2 \]
## Likelihood ratio tests results

<table>
<thead>
<tr>
<th>Models</th>
<th>Log-likelihood Value</th>
<th>LR Statistic</th>
<th>Restricted parameters</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted</td>
<td>96.116</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homogeneity</td>
<td>92.946</td>
<td>6.339</td>
<td>2</td>
<td>0.042</td>
</tr>
<tr>
<td>Symmetry</td>
<td>88.730</td>
<td>8.432</td>
<td>1</td>
<td>0.004</td>
</tr>
<tr>
<td>Own-risk*</td>
<td>76.771</td>
<td>32.351</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Risk Neutrality*</td>
<td>73.763</td>
<td>38.366</td>
<td>6</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Compare to the symmetry constrained model.
## Import demand estimates for China’s soybean imports

<table>
<thead>
<tr>
<th>Country</th>
<th>Marginal share $\theta_i$</th>
<th>Price effects $\pi_{ij}$</th>
<th>Risk effects $\nu_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brazil</td>
<td>Argentina</td>
<td>U.S.</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.487 (0.057)(^a)</td>
<td>-0.027 (0.007)(^a)</td>
<td>0.064 (0.015)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.037 (0.020)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.034 (0.012)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.022 (0.036)(^b)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.042 (0.022)(^b)</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.238 (0.046)(^a)</td>
<td>0.014 (0.006)(^b)</td>
<td>-0.154 (0.012)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.140 (0.016)(^a)</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.276 (0.026)(^a)</td>
<td>0.013 (0.009)</td>
<td>0.090 (0.019)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.103 (0.024)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.003 (0.015)(^a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.048 (0.044)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.018 (0.027)(^b)</td>
</tr>
</tbody>
</table>

Asymptotic standard errors are in parentheses.
The $R^2$ for Brazil, Argentina, and the United States are 0.89, 0.95, and 0.76, respectively.
\(a\) & \(b\) denote the 0.01 and 0.05 significance level, respectively.
## Seasonality estimates

<table>
<thead>
<tr>
<th>Month</th>
<th>Brazil</th>
<th>Argentina</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>0.024</td>
<td>-0.023</td>
<td>-0.001</td>
</tr>
<tr>
<td>Feb.</td>
<td>0.013</td>
<td>0.124</td>
<td>-0.137</td>
</tr>
<tr>
<td>March</td>
<td>-0.174*</td>
<td>-0.085</td>
<td>0.259*</td>
</tr>
<tr>
<td>April</td>
<td>0.371*</td>
<td>-0.115*</td>
<td>-0.256*</td>
</tr>
<tr>
<td>May</td>
<td>0.134*</td>
<td>0.156*</td>
<td>-0.290*</td>
</tr>
<tr>
<td>June</td>
<td>-0.036</td>
<td>0.284*</td>
<td>-0.248*</td>
</tr>
<tr>
<td>July</td>
<td>0.022</td>
<td>-0.037</td>
<td>0.016</td>
</tr>
<tr>
<td>Aug.</td>
<td>0.041</td>
<td>0.050</td>
<td>-0.091</td>
</tr>
<tr>
<td>Sep.</td>
<td>-0.014</td>
<td>-0.091*</td>
<td>0.106</td>
</tr>
<tr>
<td>Oct.</td>
<td>-0.106</td>
<td>-0.012</td>
<td>0.118</td>
</tr>
<tr>
<td>Nov.</td>
<td>-0.162*</td>
<td>-0.106*</td>
<td>0.268*</td>
</tr>
<tr>
<td>Dec.</td>
<td>-0.178*</td>
<td>-0.138*</td>
<td>0.316*</td>
</tr>
</tbody>
</table>

Asymptotic standard errors are in parentheses. * denotes a significance level ≤ 0.05.
## Import demand elasticities for China’s soybean imports

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Import</th>
<th>Brazil</th>
<th>Argentina</th>
<th>U.S.</th>
<th>Own/Cross Price</th>
<th>Brazil</th>
<th>Argentina</th>
<th>U.S.</th>
<th>Own/Cross Risk</th>
<th>Brazil</th>
<th>Argentina</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>1.366*</td>
<td>-0.075*</td>
<td>0.179*</td>
<td>-0.104</td>
<td></td>
<td>-0.096*</td>
<td>0.062</td>
<td>-0.120*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>1.061*</td>
<td>0.063*</td>
<td>-0.687*</td>
<td>0.624*</td>
<td>0.167*</td>
<td>-0.313*</td>
<td>0.273*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S.</td>
<td>0.657*</td>
<td>0.030</td>
<td>0.214*</td>
<td>-0.244*</td>
<td>-0.008</td>
<td>0.114</td>
<td>-0.043</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Asymptotic standard errors are in parentheses.
* denotes a significance level ≤ 0.05.
Summary/Conclusion

- Overall, price risk (unexplained volatility) is an important determinant of China’s soybean demand by source, even when price and seasonality effects are accounted for.

- Imports from Brazil and Argentina are decreasing in own-price risk which could indicate risk averse behavior.

- No risk effects were significant for the U.S.

- While prices in Brazil were the most volatile, imports from Argentina were the most sensitive to own-price risk.

- Price risk in competing countries have a positive effect on Argentina, but not the reverse.