China’s soybean import allocation analysis by country-of-origin

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Abstract

The purpose of this paper is to estimate China’s soybeans import allocation by country-of-origin using the input allocation model for the multiproduct firm under input-output separability. From the results, we find there is a competition between the U.S. and South America (Brazil and Argentina). Therefore, for U.S. policymakers, it might be necessary to provide certain export price support when facing strong international soybean exporting competitions.

Key Words: China soybean imports, joint production, multiproduct firm, differential approach

1. Introduction

In 2001, China became the largest importer of soybeans in the world and imported 90% (13.94 million tons) of its total amount of soybeans consumed domestically. The imports of soybeans which mainly have been GM commodity kept increasing to 63.38 million tons in 2013 (4.5 times of the imports in 2001). For more than a decade, the main three exporting countries, the U.S., Brazil and Argentina, have almost taken the whole share of the soybean importing market in China (Figure 1). It is reasonable to assume the three exporting countries as a competitive input market to China when we assume that China as a multiproduct firm takes the soybean imports from the three countries as three different inputs and jointly produces two products, soybean meal and soybean oil. Based
upon this assumption, China, as a rational economic body, will first minimize the cost of imports and then maximize the profit of production through the input allocation decision.

Figure 1. China’s soybean imports from different sources

![China's soybean imports from different sources](image)

Source: USDA Foreign Agricultural Service

Policy evaluations and welfare analysis require reliable estimates of soybean import behavior responsiveness to source differentiated prices and expenditure. In addition, import behaviors are more interesting to trade economists than domestic demand and allocation behaviors. For competitive soybean exporting countries, importers’ allocation decision and elasticities would provide important information. However, the estimates of China’s import behavior still remain open to question in the literature. Song et al. (2009) studied Chinese soybean importers’ market power against soybean exporters in the U.S. and South America, but they didn’t present the empirically estimated soybean import allocation responsiveness. Chen et al. (2012) used the differential production approach and the two-step procedure to estimate China’s demand for imported soybeans and soybean oil, both of which are
disaggregated by country-of-origin. However, we would argue that there is one pitfall in the study. The derived demand model should be applied under the restriction of one output. In their study, they assumed that there are two outputs, soybean meal and soybean oil, therefore, China should be more properly assumed as a multiproduct firm.

China’s soybean imports play an important role in deciding the international soybean prices. The purpose of this study is to provide a reliable approach and model to estimate China’s soybean import behavior and allocation elasticities. This study follows Laitinen (1980) and uses the input allocation model under the restriction that the firm is input-output separable. Sources of soybean imports are differentiated by country-of-origin.

2. Import allocation model under input-output separability

Assume that China is a multiproduct firm that faces a competitive soybean exporting market as its input market and jointly produces two products which are soybean meal and soybean oil. In this paper the three inputs are the source differentiated soybeans imported from the U.S., Brazil and Argentina, respectively, and the two outputs are soybean meal and soybean oil. Therefore, as a profit-maximizing-multiproduct firm, it will first minimize importing cost when the source differentiated input prices and products prices change\(^1\).

The input allocation equation for the \(i\) th input of the cost-minimizing-multiproduct firm (Laitinen and Theil, 1978) is written as

\[
f_i d \log q_i = \theta_i d (\log Q) + \gamma \sum_{r=1}^{m} g_r (\theta_i' - \theta_i) d (\log z_r) - \psi \sum_{j=1}^{n} \theta_j d (\log \frac{P_j}{P})
\]  

\(^1\) Laitinen (1980).
where \( f_i = \frac{p_i q_i}{C} \) is the share of the \( i \) th input in the total cost \( C \) \( (C = \sum_{i=1}^{n} p_i q_i) \); \( p_i \) is the price of the \( i \) th input (\( i = 1, \ldots, n \)); \( q_i \) is the quantity of the \( i \) th input; \( g_r = \frac{z_r}{\rho} \frac{\partial C}{\partial z_r} \) is the share of the \( r \) th product in the total marginal cost where \( \rho = \sum_{r=1}^{m} \frac{\partial C}{\partial \log z_r} \) is the marginal cost of a proportionate increase in outputs and \( z_r \) is the quantity of the \( r \) th product (\( r = 1, \ldots, m \)); \( \theta'_i = \frac{\partial(p_i q_i)}{\partial z_r} \) is the share of the \( i \) th input in the marginal cost of the \( r \) th product such that \( \sum_{r=1}^{m} g_r \theta'_i = \theta_i \) in which \( \theta_i \) is the Divisia mean of the shares \( \theta'_i \);

d(\log P) = \sum_{i=1}^{n} \theta_i d \log p_i \) is the Frisch price index of inputs, and thus \( d(\log \frac{P_i}{P}) \) is the relative price change. The coefficients, \( \theta_{ij} \), are referred to as the normalized price coefficients since \( \sum_{j=1}^{n} \theta_{ij} = \theta_i \) and \( \sum_{i=1}^{n} \sum_{j=1}^{n} \theta_{ij} = 1 \). When \( \theta_{ij} \) for \( i \neq j \) is negative (positive), the \( i \) th and \( j \) th inputs are specific substitutes (complements), since the negative \( \theta_{ij} \) implies for constant output that the firm will increase the use of the \( i \) th input when the relative price of the \( j \) th input increases. Additionally, the coefficient \( \gamma = \frac{\rho}{C} = \sum_{r=1}^{m} \frac{\partial \log C}{\partial \log z_r} \) can be interpreted as the elasticity of cost with respect to a proportionate output increase, and \( \frac{1}{\psi} = 1 + \frac{1}{\gamma^2} \sum_{r=1}^{m} \sum_{s=1}^{m} \frac{\partial^2 \log C}{\partial \log z_r \partial \log z_s} \) = \( 1 + \frac{1}{\gamma} \sum_{r=1}^{m} \frac{\partial \log \gamma}{\partial \log z_r} \) so that \( \psi \) measures the change in the elasticity which \( \gamma \) represents with respect to a proportionate change in outputs.
Laitinen and Theil (1978) shows that the total-input decision is 
\[ d(\log Q) = \gamma d(\log Z), \]
where \( d(\log Z) = \sum_{r=1}^{m} g_r d(\log z_r) \) is the Divisia volume index of outputs, and 
\[ d(\log Q) = \sum_{i=1}^{n} f_i d(\log q_i) \] is the Divisia volume index of inputs. In this function, the
associated variance is 
\[ \Gamma_i = \sum_{r=1}^{m} g_r (\theta'_r - \theta_r) [d(\log z_r) - d(\log Z)]. \]
Since \( \sum_{r=1}^{m} g_r (\theta'_r - \theta_r) d(\log Z) = (\sum_{r=1}^{m} g_r \theta'_r - \sum_{r=1}^{m} g_r \theta_r) d(\log Z) = 0^2 \), therefore, substitution yields
\[ f_i d(\log q_i) = \theta_i d(\log Q) + \gamma \Gamma_i - \psi \sum_{j=1}^{n} \theta_{ij} d(\log \frac{p_j}{P}) . \tag{2} \]

Under the restriction that the firm’s input and output are separable, the covariance \( \Gamma_i \) is necessarily zero. This means the input allocation model for the firm can be written as
\[ f_i d(\log q_i) = \theta_i d(\log Q) - \psi \sum_{j=1}^{n} \theta_{ij} d(\log \frac{p_j}{P}) \tag{3} \]

where \( -\psi \sum_{j=1}^{n} \theta_{ij} d(\log \frac{p_j}{P}) \) can be written as
\[ -\psi \sum_{j=1}^{n} \theta_{ij} d(\log p_j) + \psi \sum_{j=1}^{n} \theta_{ij} d(\log P_r) = -\psi \sum_{j=1}^{n} \theta_{ij} d(\log p_j) + \psi \theta_i d(\log P^r) . \]

Using \( d(\log P^r) = \sum_{j=1}^{n} \theta'_r d(\log p_j) \), \( -\psi \sum_{j=1}^{n} \theta_{ij} d(\log p_j) + \psi \theta_i d(\log P^r) \) can be future simplified as
\[ \sum_{r=1}^{m} g_r = 1; \sum_{r=1}^{m} g_r \theta'_r = \theta'. \] Laitinen (1980, P.37).
\[-\psi \sum_{j=1}^{n} \theta_j d(\log p_j) + \psi \theta_i \sum_{j=1}^{n} \theta_j d(\log p_j) = -\psi \sum_{j=1}^{n} (\theta_j - \theta_i \theta_j) d(\log p_j)\]. Combining these results, Eq. (3) becomes

\[f_i d \log q_i = \theta_i d(\log Q) - \psi \sum_{j=1}^{n} (\theta_j - \theta_i \theta_j) d(\log p_j).\] (4)

Define \(\pi_{ij} = -\psi \sum_{j=1}^{n} (\theta_j - \theta_i \theta_j)\), Eq. (4) can be written as

\[f_i d \log q_i = \theta_i d(\log Q) + \sum_{j=1}^{n} \pi_{ij} d(\log p_j).\] (5)

Therefore the empirical model can be written as

\[\tilde{f}_i d \log q_{it} = \theta_i d(\log Q) + \sum_{j=1}^{n} \pi_{ij} d(\log p_{it}) + \varepsilon_{it}.\]

In this study, let \(p\) and \(q\) denote the import price and quantity, the subscripts \(i\) and \(j\) \((i, j = 1, 2, 3)\) denote the exporting country, \(y\) denote the prices of the domestic consumed soybean meal and soybean oil, and the subscripts \(s\) \((s = 1, 2)\) denote the products (soybean meal and soybean oil). \(\tilde{f}_i = (f_{i,s} + f_{i,s-1})/2; d(\log x_i) = \log x_i - \log x_{i-1}\) with \(x\) representing the input price \(p\); \(d(\log Q_i) = \sum_{i=1}^{n} \tilde{f}_i d(\log q_{it})\) is the Divisia index of inputs; and others are parameters to be estimated. The adding-up conditions of the empirical model are \(\sum_{i=1}^{n} \theta_i = 1\) and \(\sum_{i=1}^{n} \pi_{ij} = 0\). The homogeneity conditions are \(\sum_{j=1}^{n} \pi_{ij} = 0\), and the symmetry conditions are \(\pi_{ij} = \pi_{ji} \forall i, j\). In addition, \(\pi_{ij}\) is negative semi-definite.

3. Data

Annual import data are provided by trademap.org and the annual soybean meal and soybean oil prices are from USDA GATS reports. The time period considered for the analysis is 2002-2013. Imports of soybeans are disaggregated by country-of-origin and the
outputs are soybean meal and soybean oil. Import value are in US dollars and import quantities are in kilograms. The import prices are the proxies of the unit values.

4. Estimation and empirical results

The input allocation model was estimated in TSP by using the Least Squares Quadratic (LSQ) method. One equation is dropped from the system, and the estimation is carried out by the left equations. And the parameters in the dropped equation can be recovered by adding up conditions.

From Table 1, we find that the marginal shares estimates are all positive and significant. This means when the total import expenditure increases, there will be a significant increase in the soybean import from each country. The estimation for the price coefficients will be discussed in details in Table 2 where the elasticities are reported.

Table 1. Import demand estimates for China’s soybean imports

<table>
<thead>
<tr>
<th></th>
<th>Marginal Share</th>
<th>US soybeans</th>
<th>Brazil soybeans</th>
<th>Argentina soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>US soybeans</td>
<td>0.4127</td>
<td>-0.2706</td>
<td>0.1113</td>
<td>0.1593</td>
</tr>
<tr>
<td></td>
<td>(-0.0856)***</td>
<td>(0.1739)</td>
<td>(0.0900)</td>
<td>(0.0872)</td>
</tr>
<tr>
<td>Brazil soybeans</td>
<td>0.2675</td>
<td>-0.0478</td>
<td>-0.0635*</td>
<td>-0.0635*</td>
</tr>
<tr>
<td></td>
<td>(-0.0785)***</td>
<td>(0.0492)</td>
<td>(0.0471)</td>
<td></td>
</tr>
<tr>
<td>Argentina soybeans</td>
<td>0.3199</td>
<td>-0.0959*</td>
<td>-0.0959*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.1093)***</td>
<td>(0.0523)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Significant at : * for 10% level, ** for 5% level, ***for 1% level

From table 2, we can see the Divisia elasticities, which measure the percent change in the soybean import from country $i$ with respect to a percent change in the total aggregated imports, are all positive and significant. Argentina is the most responsive country when China increases its total soybean imports. The own-price elasticities are all negative as expected, but only the estimate for Argentina is significant. This means when the import
price increases by one percent, China’s import from the U.S. will decrease by 0.64%, Brazil 0.15%, and Argentina 0.39%. From this result we can also see that China’s soybean imports from the U.S. is most responsive to price changes. From the cross-price elasticities, we find that the U.S. is competing with both Brazil and Argentina with the positive cross-price elasticities, though the estimate results are not significant. While from the cross-price elasticity for Argentina and Brazil, we find there is a significant complementary relationship for China’s imports from these two countries.

Table 2. Import allocation elasticities for China’s soybean imports

<table>
<thead>
<tr>
<th>Divisia Elasticity</th>
<th>US soybeans</th>
<th>Brazil soybeans</th>
<th>Argentina soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>US soybeans</td>
<td>0.9704</td>
<td>-0.6364</td>
<td>0.2617</td>
</tr>
<tr>
<td></td>
<td>(0.2012)**</td>
<td>(0.4090)</td>
<td>(0.2117)</td>
</tr>
<tr>
<td>Brazil soybeans</td>
<td>0.8135</td>
<td>-0.1454</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.2388)**</td>
<td>(0.1496)</td>
<td></td>
</tr>
<tr>
<td>Argentina soybeans</td>
<td>1.3007</td>
<td></td>
<td>-0.3898</td>
</tr>
<tr>
<td></td>
<td>(0.4443)**</td>
<td></td>
<td>(0.2125)*</td>
</tr>
</tbody>
</table>

Note: Significant at : * for 10% level, ** for 5% level, ***for 1% level

5. Conclusions

In this study, we used the differential framework to address China’s soybean import allocation choice from different sources which are differentiated by country-of-origin. By clarifying the assumptions, we applied the input allocation model for the multiproduct firm under the restriction of inputs and outputs being separable. From the estimation results, we find the U.S. is competing with Brazil and Argentina in exporting soybeans. For U.S. policymakers, it might be necessary to provide certain export price support when facing strong international soybean exporting competitions. On the other hand, Brazil and Argentina are complimentary to China’s soybean imports.
References


