China’s Soybean Imports
— Price Impacts using a Production System Approach

Wei Chen, Ph.D.
Assistant Professor
Department of Public Administration
College of Public Economics and Administration
Shanghai University of Finance and Economics
777 Guoding Road,
Yangpu District, Shanghai, China 200433
Phone: 86-25-65903686
Email: chen.wei@mail.shufe.edu.cn

Mary A. Marchant, Ph.D.
Professor
Department of Agricultural and Applied Economics
College of Agriculture and Life Sciences
Virginia Polytechnic Institute and State University
311 Hutcheson Hall
Blacksburg, VA 24061
Phone: (540) 231-1674
Email: mmarchan@vt.edu

Andrew Muhammad, Ph.D.
International Demand and Trade Branch
Market and Trade Economics Division
Economic Research Service
U.S. Department of Agriculture
1800 M Street, N.W.
Washington, DC 20036-5831
Phone: (202) 694-5226
Email: amuhammad@ers.usda.gov

Selected Paper prepared for presentation at the Southern Agricultural Economics Association
Annual Meeting, Orlando, FL, February 6-9, 2010

Copyright 2010 by Wei Chen, Mary A. Marchant, and Andrew Muhammad. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
China’s Soybean Imports —
Price Impacts using a Production System Approach

Abstract
A differential production model is applied to study how soybean and soybean oil imports from the U.S., Brazil and Argentina compete on China’s markets and how China’s domestic prices of soybean meal and oil impact the country’s imports. The results support a presumption that China’s soybean imports from global markets are impacted by China’s domestic soybean meal price but not by the soybean oil price.

a) Introduction

Soybeans lead U.S. bulk agricultural commodity exports and China is the U.S. top market. In 2008 U.S. exported 33.8 million metric tons (MMT) of soybeans, valued at $8.1 billion, with 46 percent of it exported to China. The U.S., Brazil and Argentina dominate China’s soybean import markets and these countries consistently account for 99 percent of China’s soybean imports. In 2007/08 (October 2007 – September 2008), China imported 37.8 MMT of soybeans, and the U.S., Brazil and Argentina accounted for 36, 33 and 29 percent, respectively.

China’s domestically planted soybeans were primarily used to produce food. The large quantity of China’s soybean imports stems from its rapidly growing crush consumption to produce soybean meal and oil. In 2007/08 crush consumption accounted for 79 percent of China’s total soybean consumption and reached 39.3 MMT. Soybean imports supplied 96 percent of China’s crush consumption. China constructed massive soybean crushing infrastructure along its coastline. China’s crushing capacity reached 80 MMT in 2007, more than double the country’s actual use, 39.5 MMT in 2007/08. However, in addition to importing soybeans, China imported 2.7 MMT of soybean oil from the same three countries in 2007/08; while its

We very appreciate Drs. Jim Hansen and Francis Tuan from ERS, USDA for their help of providing China’s import data for this research.
meal imports were nil.

The joint product nature of soybeans, as well as China’s excess crushing capacity raises a key research question: **Why does China import soybean oil, while half of its soybean crushing capacity remains unused?** One possible explanation stems from the derived demand for meal. Crushing 100 MMT of soybeans can produce 18 MMT of soybean oil and 79 MMT of soybean meal. China’s soybean meal consumption was supplied by crushing its soybean imports. If China did not import soybean oil directly, the crushing ratios indicate that an additional 15 MMT of soybeans would have to be imported to meet its demand for soybean oil in 2007/08 and produce an additional 11.9 MMT of soybean meal. Soybean meal is very high in protein content and difficult to store. This problem may discourage China from importing additional soybeans to meet its domestic soybean oil demand. Thus, our hypothesis is that China’s soybean imports are impacted by its domestic soybean meal prices but not by its domestic soybean oil prices.

b) Literature Review

Sarwar and Anderson (1990) set up a simultaneous supply and demand equation model to investigate U.S. soybean exports to different regions. Sarwar and Anderson’s approach is from the perspective of the U.S., the exporting country. The estimated short-term own-price elasticity of export demand is -0.63 for developed countries, -0.42 for Asian countries, and -3.62 for Latin American countries.

Song et al. (2009) apply a simultaneous equation system to analyze
competitiveness of China’s three soybean suppliers by investigating the relationship between China’s soybean imports and soybean stocks in exporting areas. The paper concludes that China’s soybean imports from the U.S. and South America are seasonally complementary to each other and South American countries’ soybean exports to China can be a complete substitute for the U.S. exports, while U.S. soybean exports are just a partial substitute for South American countries’ exports to China.

For the soybean crushing industry, soybeans are raw products, from which two joint products – soybean meal and oil – are produced. Piggott and Wohlgenant (2002) develop an equation system containing both domestic and foreign markets for soybeans and soybean products. This system is based on Houck’s (1964) model for joint products. Piggott and Wohlgenant (2002) conclude that taking account of trade in soybean oil and meal has a more profound impact on the responsiveness of total soybean demand than only taking into account soybeans. Therefore, research in this thesis takes into account soybean meal and oil prices in China’s domestic markets.

Davis and Jensen (1994) point out that although in a two-stage utility maximization model imported agricultural commodities are treated as final goods; in fact, most imported agricultural commodities are inputs. For example, China imports soybeans to produce soybean meal and oil, and China’s consumers do not consume imported soybeans directly. This conceptual misspecification leads to biased estimation and inference. Davis and Jensen (1994) propose a two-stage profit maximization model based on producer theory to overcome this limitation. This producer theory approach consists of two stages: profit maximization and cost
minimization, and encompass virtues of conditional demand systems derived from consumer theory. In the profit maximization stage and can be used to estimate unconditional elasticities and structural parameters.

The differential production model is a member of the two-stage profit maximization family. This model is proposed in Laitinen and Theil (1978), Laitinen (1980) and Theil (1980). A total-import expenditure equation and import-demand system are derived in this two-stage profit maximization procedure. In recent years, this method has been applied to topics like EU’s fish imports (Muhammad 2007) and U.S. lamb imports (Muhammad et. al 2007). In this paper, the differential production model is adopted to analyze the effects of international and China’s domestic prices on China’s soybean imports.

c) Data and Methods

Monthly values and quantities of China’s soybeans imports are collected from World Trade Atlas. China’s domestic monthly prices for soybeans, soybean meal and oil are obtained from USDA, FAS. All prices are real U.S. dollars, adjusted by using Producer Price Index (PPI) for soybeans (Bureau of Labor Statistics). Analysis focuses on China membership in the WTO and uses data from January 2002 to December 2008. This differential production model is estimated and the elasticities are solved to test the hypothesis.

To test the hypothesis, imported soybeans are treated as inputs. A differential production model, developed by Laitinen and Theil, is applied. It is derived from
producer theory and consists of two stages: cost minimization and profit maximization. A detailed description of the model is available in Appendix B. Solving a cost minimization problem for China’s soybean crushing industry, China’s demand for soybean and soybean oil imports from the three countries are expressed as functions of outputs of soybean meal and oil, and prices of China’s soybean and soybean oil imports from these countries:

\[
(1) \quad \bar{f}_u \Delta x_u = \sum_{r=1}^{2} \theta_r^i \Delta q_{rt} + \sum_{j=1}^{5} \pi_j^i \Delta w_{j\beta} + \sum_{m=1}^{12} \rho_{jm} D_m ,
\]

where

\[
\bar{f}_u = \left( f_u + f_{u-12} \right) / 2, \quad \Delta x_u = \log x_u - \log x_{u-12} , \quad \Delta q_{rt} = \bar{f}_r \bar{g}_{rt} \Delta q_{rt} ,
\]

\[
\Delta q_{rt} = \log q_{rt} - \log q_{rt-12} , \quad \bar{f}_r = \left( R_r R_{r-12} / C_r C_{r-12} \right)^{1/2} , \quad \bar{g}_{rt} = \left( g_{rt} + g_{rt-12} \right) / 2 \quad \text{and}
\]

\[
\Delta w_{j\beta} = \log w_{j\beta} - \log w_{j\beta-12} .
\]

\( f_u \): the market shares of China’s soybean and soybean oil imports from global markets with \( i \in I = \{1,2,3,4,5\} \), 1: China’s soybean imports from the U.S., 2: China’s soybean imports from Brazil, 3: China’s soybean imports from Argentina, 4: China’s soybean oil imports from Brazil, 5: China’s soybean oil imports from Argentina;

\( x_u \): the monthly quantity of China’s soybean and soybean oil imports from global markets;

\( q_{rt} \): the monthly quantity of China’s soybean meal and oil production, \( r \in R = \{1,2\} \), 1: China’s soybean meal production, 2: China’s soybean oil production;

\( g_{rt} \): the share of China’s soybean meal and oil production in the total revenue of crushing soybeans;
$R_i$: the monthly total revenue of producing soybean meal and oil on China’s domestic markets;

$C_i$: the monthly total cost of importing soybeans and soybean oil;

$w_j$: the monthly prices of China’s soybean and soybean oil imports from each country with $j \in I = \{1, 2, 3, 4, 5\}$;

$D_m$: monthly dummy variables.

According to the producer theory, price coefficient, $\pi_j$, is expected to be negative for $i = j$. This means that when the price of China’s soybean imports from country $i$ increases, China’s soybean imports from this country are expected to decrease. For $i \neq j$, when the price of China’s soybean imports from country $j$ increases, China’s soybean imports from country $i$ are expected to increase, i.e. $\pi_j > 0$, if imports from countries $i$ and $j$ are substitutes. If imports from countries imports from countries $i$ and $j$ are complements, then $\pi_j < 0$, and when the price of China’s soybean imports from country $j$ increases, China’s soybean imports from country $i$ are expected to decrease. Marginal factor share, $\theta_i'$, measures when China’s total soybean imports increase, how its soybean imports from a specific source country change. In estimation, a series of constraints derived from producer theory will be imposed when conducting estimation. These constraints are $\sum_{i=1}^{n} \theta_i' = 1$, $\sum_{i=1}^{n} \pi_{ij} = 0$ (adding up), $\sum_{j=1}^{n} \pi_{ij} = 0$ (homogeneity), and $\pi_{ij} = \pi_{ji}$ (symmetry).

Solving a profit maximization problem, China’s domestic outputs of soybean meal and oil are functions of China’s domestic soybean meal and oil prices, prices of China’s soybean imports from these countries, and prices of other input factors like
labor and energy. The output supply system to be estimated is as follows:

\[
(2) \quad \Delta q_{it}^* = \sum_{s=1}^{2} \phi_{rs}^* \Delta p_{st} + \sum_{i=1}^{5} \pi_{ri}^* \Delta w_{si} + \sum_{k=1}^{2} \phi_{rk}^* \Delta w_{kt}^* + \sum_{m=1}^{12} \zeta_{im} D_{mi} ,
\]

where

\[
\Delta p_{st} = \log p_{st} - \log p_{st-12} \quad \text{and} \quad \Delta w_{kt}^* = \log w_{kt}^* - \log w_{kt-12}^* .
\]

\(p_{st}:\) the monthly prices of soybean meal and soybean oil on China’s domestic markets;

\(w_{kt}^*:\) the resource prices of crushing soybeans, with \(k \in K = \{1,2\},\) 1: wage, 2: electricity power.

The producer theory indicates the constrains, \(\sum_{s=1}^{m} \phi_{rs}^* + \sum_{i=1}^{n} \pi_{ri}^* = 0\) (homogeneity), and \(\phi_{rs}^* = \phi_{sr}^*, \pi_{ri}^* = -\sum_{s=1}^{m} \phi_{rs}^* \theta_{i}^*\) (symmetry) should be imposed in estimation. In the output supply system, \(\pi_{i}^*\), measures when the price of China’s soybean imports from a specific country increases, how the total import expenditure changes. Output price coefficient, \(\varphi_{i}^*\), is expected to be positive. This represents that when China’s domestic soybean oil or meal price increases, China’s total soybean imports should increase.

Estimates of the differential production model can be applied to calculate elasticities of the model. Conditional own-price/cross-price elasticity is:

\[
(3) \quad \eta_{ij} = \frac{d (\log x_{i})}{d (\log w_{j})} = \frac{\pi_{ij}^*}{f_{i}^*} .
\]

Equation (3) measures when the price of China’s soybean or soybean oil imports from country \(j\) increases one percent, how imports from country \(i\) will change, holding other imports constant. For \(i = j\), equation (3) is conditional own-price elasticity. For
\( i \neq j \), equation (3) is conditional cross-price elasticity.

Unconditional own-price/cross-price elasticity is

\[
\eta_i = \frac{d \left( \log x_i \right)}{d \left( \log w_j \right)} = \frac{\pi_i}{\pi_w} + \sum_{r=1}^{2} \theta_{ij}^r \phi_{ij}^r.
\]

Equation (4) measures when the price of China’s soybean or soybean oil imports from country \( j \) increases one percent, how imports from country \( i \) will change, considering effects through China’s total soybean imports. For \( i = j \), equation (4) is unconditional own-price elasticity. For \( i \neq j \), equation (4) is unconditional cross-price elasticity.

Unconditional output price elasticity is

\[
\eta_v = \frac{d \left( \log x_i \right)}{d \left( \log p_r \right)} = \sum_{s=1}^{2} \theta_{s}^r \phi_{s}^r.
\]

Equation (5) measures when the price of China’s domestic soybean meal or oil increases one percent how China’s soybean imports from a specific country change.

d) Estimation Results

The demand and supply system are estimated separately using ITSUR method. The estimates of the demand system are contained in Table 1 in Appendix A. They indicate that China’s soybean imports from the U.S. are negatively impacted by its own price and China’s soybean oil output but positively impacted by the prices of China’s soybean oil imports from Brazil and Argentina and China’s soybean meal output. China’s soybean imports from Brazil are positively impacted by China’s soybean meal output. China’s soybean imports from Argentina are impacted by its own price but the
sign is positive. By symmetry, China’s soybean oil imports from Brazil and Argentina are positively impacted by the price of China’s soybean imports from the United State. China’s soybean oil imports from Argentina are negatively impacted by China’s soybean meal production.

*Table 1*

Table 2 contains estimates of the output supply system. China’s soybean meal supply is negatively impacted by the prices of China’s soybean imports from the U.S. and Brazil and China’s domestic labor wage. China’s soybean oil supply is negatively impacted by the price of China’s soybean oil imports from Brazil and China’s domestic labor wage. However, except the labor wage price, all the import price impacts are very small. The estimates of monthly dummy variables are contained in Table 3. Although soybeans from the U.S. and South American countries have different import seasons, the month impacts hardly impact China’s soybean and soybean oil imports.

*Table 2*

*Table 3*

The unconditional import price and output price elasticities are displayed in Table 5. The standard deviations are calculated by using Monte Carlo simulation method. China’s soybean imports from the U.S. are elastic to its own price and the price of soybean oil imports from Argentina. For every one per cent increase in the price, China’s soybean imports from the U.S. will decrease 0.7754 per cent. However, when the price of soybean oil from Argentina increases one per cent, China’s soybean imports from the U.S. will increase 1.6415 per cent. When the soybean meal price increases,
China’s soybean imports from the U.S. will increase as well. China’s soybean imports from Argentina will increase, when the price of soybean imports from Argentina increase. This positive own-price elasticity is also found in China’s soybean oil imports from Brazil. China’s soybean imports from Argentina are also impacted by China’s domestic soybean meal price, but the magnitude is very small.

[Table 5]

The unconditional elasticities indicate that China’s soybean imports from the U.S. are own-price elastic and China’s soybean oil imports from Argentina are its substitute. However, China’s soybean imports from America are not substitutes for China’s soybean or soybean oil imports from Brazil and Argentina. Moreover, China’s soybean oil imports from Brazil increase as its own price increases.

The price of soybean meal but not soybean oil significantly affected China’s soybean imports from the U.S. and Argentina. This is consistent with the presumption that China’s soybean imports are impacted by its domestic soybean meal prices but not by its domestic soybean oil prices. However, the values of the elasticities indicate that these effects are very small.

e) Conclusions

This paper applies a differential production model to study how China’s soybean imports from different countries compete with each other on China’s market and how they are affected by China’s domestic soybean meal and oil prices.

The results indicate that China’s domestic soybean meal price affects its soybean
imports from global markets but the effect of soybean oil price is not significant, but the
effect of soybean meal price is very small. China’s soybean imports from the U.S. are
negatively impacted by its own price. However, the imports of soybeans from
Argentina and soybean oil from Brazil are positively impacted by their own prices,
respectively. This may imply that a research from the perspective of soybean and
soybean oil exports from Argentina and Brazil should be conducted in future.
References

http://www.bls.gov/ppi/.

Davis, George C. and Kim L. Jensen (1994). “Two-Stage Utility Maximization and
Import Demand Systems Revisited: Limitations and an Alternative.” Journal of

Economics, 46:3, 652-656.


Holland Publishing Company.

Access on EU Demand for Imported Fish: Implications for Lake Victoria Chilled
Fillet Exports.” European Review of Agricultural Economics. 34:4, 461-477.

Domestic and Import Prices on U.S. Lamb Imports: A Production System

Products, and International Trade,” Australian Journal of Agricultural and Resource


Song, Baohui, Mary A. Marchant, and Michael R. Reed (2009). “Competitive Analysis
and Market Power of China's Soybean Import Market,” International Food and
Agribusiness Management Review. 12:1. Available on the web:

Chicago Press.

United States Department of Agriculture, Foreign Agriculture Service (USDA, FAS).
“GAIN Report Number China, Peoples Republic of Oilseeds and Products Annual:
Part 1 of 2 – Analysis,” Report Number CH4010 for 2004, CH5017 for 2005, CH6006
## Appendix A. Tables

### Table 1. Estimates of China’s Soybean and Soybean Oil Imports

<table>
<thead>
<tr>
<th>China’s Imports</th>
<th>Import Price Coefficients</th>
<th>Output Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybeans from the U.S.</td>
<td>Soybeans from Brazil</td>
</tr>
<tr>
<td>Soybeans from the U.S.</td>
<td>-0.2615 (0.1330) **</td>
<td>-0.0778 (0.1602)</td>
</tr>
<tr>
<td>Soybeans from Brazil</td>
<td>0.1016 (0.3108)</td>
<td>-0.0310 (0.2572)</td>
</tr>
<tr>
<td>Soybeans from Argentina</td>
<td>0.6851 (0.3876) *</td>
<td>-0.0072 (0.0137)</td>
</tr>
<tr>
<td>Soybean Oil from Brazil</td>
<td>0.02089 (0.0077) ***</td>
<td>-0.0143 (0.0152)</td>
</tr>
<tr>
<td>Soybean Oil from Argentina</td>
<td>-0.1342 (0.3765)</td>
<td>-1.8470 (0.6940) **</td>
</tr>
</tbody>
</table>

**Equation**

0.37 0.18 0.22 0.31 0.30

***, ** and * Significance level at 1, 5 and 10 per cent

### Table 2. Estimates of China’s Soybean Meal and Oil Supply

<table>
<thead>
<tr>
<th>China’s Markets Supply</th>
<th>Import Price Coefficients</th>
<th>Output Coefficients</th>
<th>Price</th>
<th>Resource Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybeans from the U.S.</td>
<td>Soybeans from Brazil</td>
<td>Soybeans from Argentina</td>
<td>Soybean Oil from Brazil</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>-0.0042 (0.0017) ***</td>
<td>-0.0015 (0.0007) ***</td>
<td>0.0006 (0.0146)</td>
<td>-0.0001 (0.0001) ***</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>0.0026 (0.0208) **</td>
<td>0.0007 (0.0064) **</td>
<td>0.0025 (0.0086) **</td>
<td>-0.00004 (0.00002) **</td>
</tr>
</tbody>
</table>

***, ** and * Significance level at 1, 5 and 10 per cent
### Table 3. Estimates of Monthly Dummy Variables in Demand and Supply Systems

<table>
<thead>
<tr>
<th></th>
<th>Import Demand System</th>
<th>Output Supply System</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybeans from the U.S.</td>
<td>Soybeans from Brazil</td>
<td>Soybeans from Argentina</td>
<td>Soybean Oil from Brazil</td>
<td>Soybean Oil from Argentina</td>
<td>Soybean Meal</td>
<td>Soybean Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>0.0634 (0.0925)</td>
<td>0.1798 (0.0818) **</td>
<td>0.1409 (0.1070)</td>
<td>0.0003 (0.0039)</td>
<td>-0.0037 (0.0089)</td>
<td>-0.0581</td>
<td>-0.0397</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0492</td>
<td>-0.0060</td>
<td>0.1453</td>
<td>0.0017</td>
<td>-0.0011</td>
<td>0.0003</td>
<td>(0.0903)</td>
<td>0.0726</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td>0.1119 (0.0941)</td>
<td>0.1254</td>
<td>(0.0050)</td>
<td>(0.0109)</td>
<td>**</td>
<td>**</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0969</td>
<td>-0.0166</td>
<td>0.1472</td>
<td>0.0025</td>
<td>0.0108</td>
<td>0.4136</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>0.0765 (0.1073)</td>
<td>0.0812</td>
<td>0.0364</td>
<td>0.0075</td>
<td>0.0081</td>
<td>0.0969</td>
<td>0.0632</td>
<td>0.30567</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0924 (0.0900)</td>
<td>0.1206</td>
<td>(0.0053)</td>
<td>(0.0105)</td>
<td>***</td>
<td>***</td>
<td>(0.0724)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>0.0934 (0.0820)</td>
<td>0.1072</td>
<td>0.0054</td>
<td>0.0090</td>
<td>0.0902</td>
<td>0.0920</td>
<td>0.0726</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0934 (0.0830)</td>
<td>0.1089</td>
<td>0.0056</td>
<td>0.0079</td>
<td>0.0983</td>
<td>0.0720</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>0.0935 (0.0765)</td>
<td>0.1005</td>
<td>0.0056</td>
<td>0.0083</td>
<td>0.0891</td>
<td>0.0720</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>0.0866 (0.0880)</td>
<td>0.0366</td>
<td>0.0072</td>
<td>-0.0012</td>
<td>0.0370</td>
<td>0.0361</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>0.0826 (0.0729)</td>
<td>0.0960</td>
<td>0.0054</td>
<td>0.0080</td>
<td>0.0825</td>
<td>0.0660</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>0.1122</td>
<td>0.0677</td>
<td>0.0115</td>
<td>0.0053</td>
<td>-3.371e-06</td>
<td>0.0717</td>
<td>0.0491</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>0.0934</td>
<td>0.0460</td>
<td>0.1426</td>
<td>0.0083</td>
<td>0.0016</td>
<td>-0.1717</td>
<td>0.0646</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>0.0876 (0.0752)</td>
<td>(0.0999)</td>
<td>0.0054</td>
<td>(0.0086)</td>
<td>0.0803**</td>
<td>0.0690</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>0.0828 (0.0723)</td>
<td>0.0955</td>
<td>0.0053</td>
<td>**</td>
<td>0.0803</td>
<td>0.0646</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>0.0847 (0.0773)</td>
<td>0.1006</td>
<td>0.0055</td>
<td>0.0082</td>
<td>0.0801</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***, ** and * Significance level at 1, 5 and 10 per cent
### Table 4. Conditional Price and Output Elasticities

<table>
<thead>
<tr>
<th>China's Imports</th>
<th>Own- and Cross-Price Elasticities</th>
<th>Output Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybeans from the U.S.</td>
<td>Soybeans from Brazil</td>
</tr>
<tr>
<td>Soybeans from the U.S.</td>
<td>-0.7413 (0.3472) **</td>
<td>-0.2206 (0.4541)</td>
</tr>
<tr>
<td>Soybeans from Brazil</td>
<td>-0.2666 (0.5489)</td>
<td>0.3483 (1.0649)</td>
</tr>
<tr>
<td>Soybeans from Argentina</td>
<td>-1.0391 (0.9455)</td>
<td>-0.1433 (1.1892)</td>
</tr>
<tr>
<td>Soybean Oil from Brazil</td>
<td>0.0796 (0.1979)</td>
<td>-0.0610 (0.4106)</td>
</tr>
<tr>
<td>Soybean Oil from Argentina</td>
<td>5.2717 (1.6961)***</td>
<td>0.0859 (2.2426)</td>
</tr>
</tbody>
</table>

***, ** and * Significance level at 1, 5 and 10 per cent

### Table 5. Unconditional Price and Output Price Elasticities

<table>
<thead>
<tr>
<th>China's Imports</th>
<th>Own- and Cross-Price Elasticities</th>
<th>Output Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybeans from the U.S.</td>
<td>Soybeans from Brazil</td>
</tr>
<tr>
<td>Soybeans from the U.S.</td>
<td>-0.7754 (0.3767) **</td>
<td>-0.2314 (0.4671)</td>
</tr>
<tr>
<td>Soybeans from Brazil</td>
<td>-0.2797 (0.5523)</td>
<td>0.3441 (1.0053)</td>
</tr>
<tr>
<td>Soybeans from Argentina</td>
<td>-1.0550 (0.9595)</td>
<td>-0.1484 (0.1882)</td>
</tr>
<tr>
<td>Soybean Oil from Brazil</td>
<td>0.0783 (0.1972)</td>
<td>-0.0614 (0.4056)</td>
</tr>
<tr>
<td>Soybean Oil from Argentina</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

***, ** and * Significance level at 1, 5 and 10 per cent
Appendix B. The Differential Production Model

B.1. Input Demand Equations

From Laitinen and Muhammad, generally, the input demand equation system in the matrix form is

\[(B.1) \quad F d(\log x) = \gamma K G d(\log q) - \psi (\Theta - \Theta') d(\log w).\]

Variable Definitions:

\[\chi = [x_1', \ldots, x_n']\] is the vector of \(n\) input quantities.

\[\varrho = [q_r', \ldots, q_m']\] is the vector of \(m\) output quantities.

\[\omega = [w_r', \ldots, w_n']\] is the vector of \(n\) input prices.

Parameter Definitions:

\[F_{nn}\] is a diagonal matrix with factor cost shares, \(f_i = w_i x_i / \sum_{i=1}^{n} w_i x_i\), along the diagonal.

\[\gamma = \sum_{r=1}^{m} \frac{\partial \log C}{\partial \log q_r}\] (Laitinen, 1980, P34 (3.13)) is the elasticity of cost with respect to a proportionate output increase, where \(C = \sum_{i=1}^{n} w_i x_i\) is the cost function.

\[K_{nm}\] is a matrix with \((i, \cdot)\)th element.

\[G_{nm}\] is a diagonal matrix with the product shares, \(g_r = -\frac{\partial h(x(q, w), q)}{\partial \log q_r}\) (Laitinen, 1980, P36 (3.21) and P19 (2.14)) , along the diagonal, where \(h(x, q) = \log [d(x, q)]\) and \(d(x, q)\) is a distance function and \(d(x, q) = 1\).
represents the firm’s production technology.

\[ \Theta_{n \times n} = [\theta_{ij}] \] is a matrix defined by \[ \Theta = \frac{1}{\psi} F (F - \gamma H)^{-1} F \] and

\[ \psi = \epsilon^T F (F - \gamma H)^{-1} F \epsilon \] with \[ L_{n \times 1} = [1, ..., 1]' \] and \[ H = \frac{\partial^2 h(x,q)}{\partial (\log x) \partial (\log y')} \].

\[ \theta = \Theta L, \quad \sum_{j=1}^{n} \theta_{ij} = \sum_{j=1}^{n} \theta_{ij} \] and \[ \epsilon^T \theta = 1 \]

For a multiple output firm, the derived input demand equation for the \( i \)th input is

\[ (B.2) \quad f_i d(\log x_i) = \gamma \sum_{r=1}^{m} \theta_{ir}^r g_r d(\log q_r) - \psi \sum_{j=1}^{n} (\theta_{ij} - \theta_{ij}) d(\log w_j) \]

Equation \( (B.2) \) can be rewritten as

\[ (B.3) \quad f_i d(\log x_i) = \sum_{r=1}^{m} \theta_{ir}^r d(\log q_r^* ) + \sum_{j=1}^{n} \pi_{ij} d(\log w_j) \]

where \[ \pi_{ij} = -\psi (\theta_{ij} - \theta_{ij}) \] and \[ d(\log q_r^*) = \gamma g_r d(\log q_r) \] in equation \( (B.3) \). Three constraints derived from production theories on equation \( (B.3) \) are

\[ (B.4) \quad \sum_{i=1}^{n} \theta_{ir}^r = 1, \quad \sum_{j=1}^{n} \pi_{ij} = 0 \] (adding up) (Laitinen 1980, P114-115);

\[ (B.5) \quad \sum_{j=1}^{n} \pi_{ij} = 0 \] (homogeneity); and

\[ (B.6) \quad \pi_{ij} = \pi_{ji} \] (symmetry).

In empirical studies, \[ d(\log z_i) \] cannot be observable, where \( z_i \) represents variables in equation \( (B.3) \). A finite version of equation \( (B.3) \) was proposed in Laitinen (1980):

\[ (B.7) \quad \bar{f}_i \Delta x_i = \sum_{r=1}^{m} \theta_{ir}^r \Delta q_r^* + \sum_{j=1}^{n} \pi_{ij} \Delta w_j, \]

where \[ \bar{f}_i = \left( f_i + f_{i-12} \right)/2 \], \[ \Delta x_i = \log x_i - \log x_{i-12} \], \[ \Delta q_r^* = \bar{y}_r \bar{g}_r \Delta q_{rt} \].
\[ \Delta q_t = \log q_t - \log q_{t-12} , \quad \bar{\gamma}_t = \left( R_{t-12} / C_{t-12} \right)^{\frac{1}{2}} , \quad \bar{g}_{rt} = \left( g_{rt} + g_{r,t-12} \right) / 2 , \]
and
\[ \Delta w_t = \log w_t - \log w_{t-12} \). The seasonality is considered by adding a monthly dummy variable, \( D_m \), and the finite version is
\[ (B.8) \quad \bar{\gamma}_t \Delta x_t = \sum_{r=1}^{m} \theta_{r}^{\ast} \Delta q_{r}^{\ast} + \sum_{j=1}^{n} \pi_{j} \Delta w_{j} + \sum_{m=1}^{12} \rho_{m} D_{m} \].

\section*{B.2. Output Supply Equation}

From Laitinen and Muhammad, the output supply equation in the matrix form is
\[ (B.9) \quad G d \left( \log q \right) = \psi^{\ast} \Theta^{\ast} \left[ d \left( \log p \right) - K^\prime d \left( \log w \right) \right] \]

Parameter Definitions:

\( G_{m \times m} \) is a diagonal matrix with the product shares, \( g_r = -\partial h \left( x, q, w \right) / \partial \log q_r \), along the diagonal, where \( h \left( x, q \right) = \log \left[ d \left( x, q \right) \right] \) and \( d \left( x, q \right) \) is a distance function and \( d \left( x, q \right) = 1 \) represents the firm’s production technology.
\[ \psi^{\ast} \geq \psi \left( \gamma - \psi \right) . \]

\( \Theta^{\ast} = \left[ \theta_{r}^{\ast} \right] \) is a matrix defined by \( \psi^{\ast} \Theta^{\ast} = G \frac{\partial \log z}{\partial \log y'} \)
\[ K_{m \times m}^\prime = \left( K_{m \times m} \right)^{\prime} , \text{ where } K_{m \times m} \text{ is a matrix with } \theta_{r}^{\prime} = \frac{\partial \left( w_{r} x_{r} \right)}{\partial q_{r}} / \frac{\partial C}{\partial q_{r}} \text{ as its} \]
\( (i, \cdot) \text{th element.} \)

For a multiple output firm, the derived output supply equation for the \( rth \) output is
\[ (B.10) \quad g_r d \left( \log q_r \right) = \psi^{\ast} \sum_{s=1}^{m} \theta_{r}^{\ast} \left[ d \left( \log p_s \right) - \sum_{i=1}^{n} \theta_{i}^{\prime} d \left( \log w_i \right) \right] . \]

Equation (B.10) can be rewritten as,
\[ (B.11) \quad g_r d \left( \log q_r \right) = \sum_{s=1}^{m} \psi^{\ast} \theta_{r}^{\ast} \left( d \left( \log p_s \right) \right) + \sum_{s=1}^{m} \left( -\psi^{\ast} \right) \theta_{r}^{\ast} \sum_{i=1}^{n} \theta_{i}^{\prime} d \left( \log w_i \right) . \]
Multiply both sides of equation (B.11) by $\gamma$,

\[(B.12) \quad \gamma g_d (\log q_v) = \sum_{s=1}^{m} \varphi_{rs}^* d (\log p_s) + \sum_{i=1}^{n} \pi_{ri}^* d (\log w_i),\]

where $\varphi_{rs}^* = \gamma \psi^* \theta_{rs}^*$ and $\pi_{ri}^* = \gamma \theta_i^* \sum_{s=1}^{m} (-\psi^*) \theta_{rs}^*$. Two constraints derived from production theories on equation (B.12) are

\[(B.13) \quad \sum_{s=1}^{m} \varphi_{rs}^* + \sum_{i=1}^{n} \pi_{ri}^* = 0 \quad \text{(homogeneity)};\]

and

\[(B.14) \quad \varphi_{rs}^* = \varphi_{rs}^* \quad \text{(symmetry)}.\]

Moreover, if symmetry is imposed both on input demand and output supply equation system, in addition to equation (B.14), it will be required that.

\[(B.15) \quad \pi_{ri}^* = -\sum_{s=1}^{m} \varphi_{rs}^* \theta_{ri}^* ,\]

which is easily derived from $K = K'$. A finite version of equation (B.12) is

\[(B.16) \quad \Delta q_{it}^* = \sum_{s=1}^{m} \varphi_{rs}^* \Delta p_{st} + \sum_{i=1}^{n} \pi_{ri}^* \Delta w_{it} ,\]

where $\Delta p_{it} = \log p_{it} - \log p_{it-12}$. The resource prices, $w_{it}^*$, are included in the output supply system and the finite version is

\[(B.17) \quad \Delta q_{it}^* = \sum_{s=1}^{m} \varphi_{rs}^* \Delta p_{st} + \sum_{i=1}^{n} \pi_{ri}^* \Delta w_{it} + \sum_{k=1}^{b} \phi_{ik} \Delta w_{kt}^* .\]

Including monthly dummy variables $D_m$, the finite version model to be estimated is
\[
\begin{align*}
\bar{f}_t \Delta x_t &= \sum_{r=1}^{m} \theta_r^\ast \Delta q_{rr}^\ast + \sum_{j=1}^{n} \pi_j^\ast \Delta w_{jt} + \sum_{m=1}^{12} \rho_m D_m \\
\Delta q_{rr}^\ast &= \sum_{s=1}^{m} \phi_{rs}^\ast \Delta p_{rt} + \sum_{j=1}^{n} \pi_{js}^\ast \Delta w_{jt} + \sum_{k=1}^{h} \phi_{rk}^\ast \Delta w_{kt} + \sum_{m=1}^{12} \zeta_m D_m
\end{align*}
\]