Foreign Price Risk and Homogeneous Commodity Imports:

A Focus on Soybean Demand in China

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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…

- **Price risk and import demand, aggregate trade flows:** Anderson and Garcia, 1989; Pick, 1990; Appelbaum and Kohli, 1997, 1998; Langley et al., 2000; Cho, Sheldon and McCorriston, 2002; Appelbaum and Woodland, 2010.
- **Import allocation and price risk:** Wolak and Kolstad (1991) (Japanese steam-coal imports), and Seo (2001) (Chinese wheat imports).

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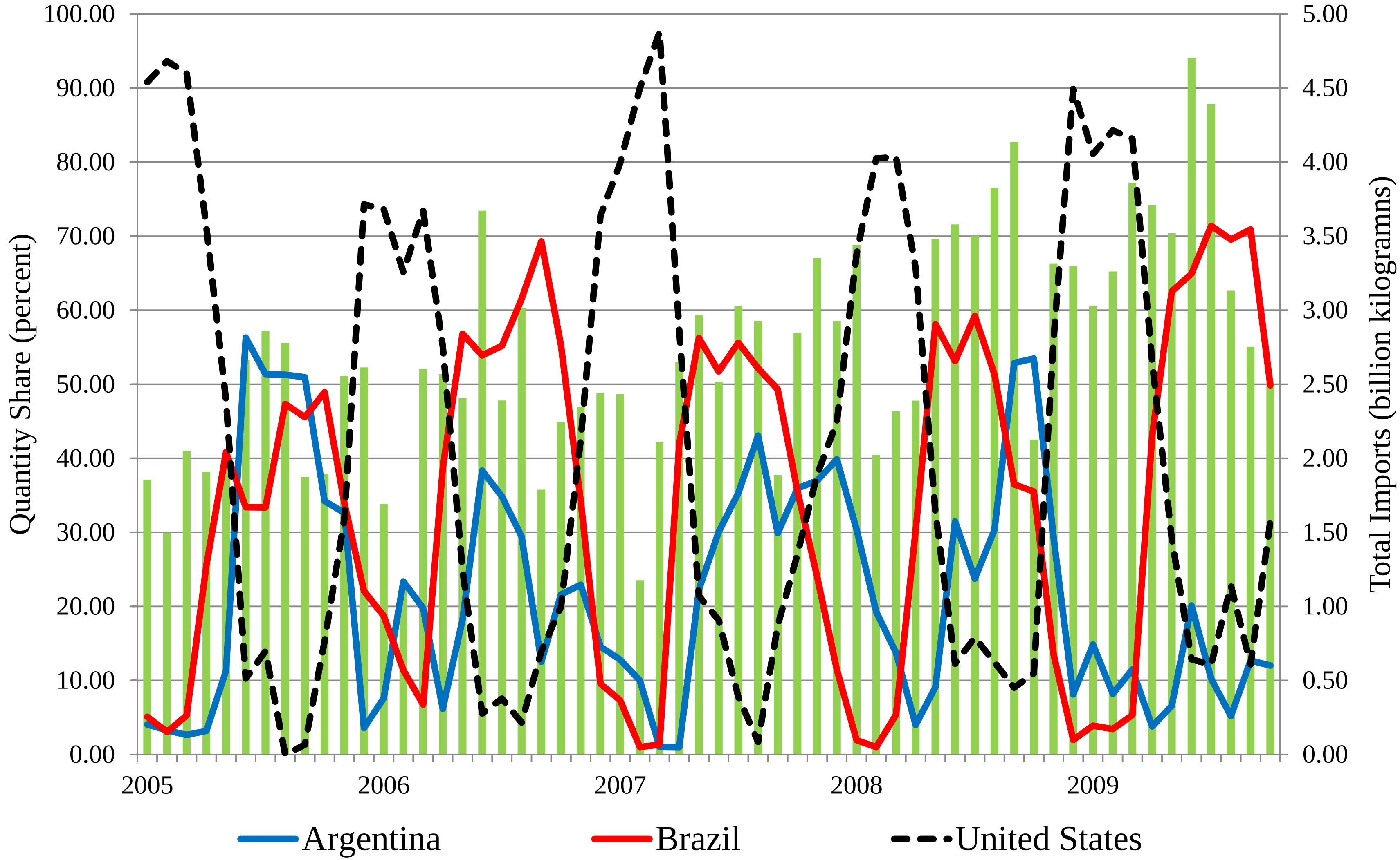
China's Soybean Imports: Jan. 2005-Dec. 2009
(billion kilograms)



Source: World Trade Atlas Database

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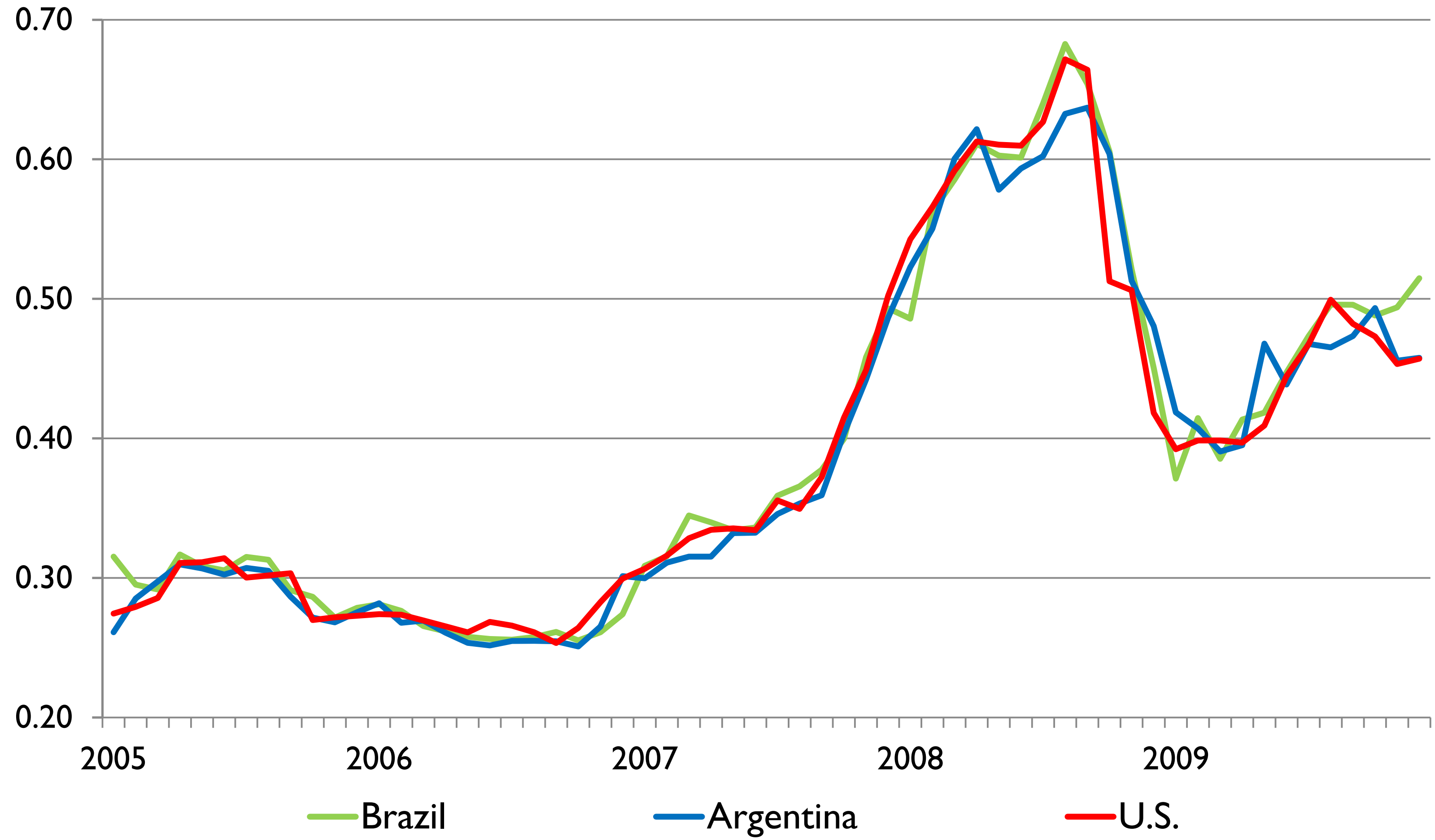
China's Soybean Prices by Exporter: Jan. 2005-Dec. 2009
($US per kilograms)



Source: World Trade Atlas Database

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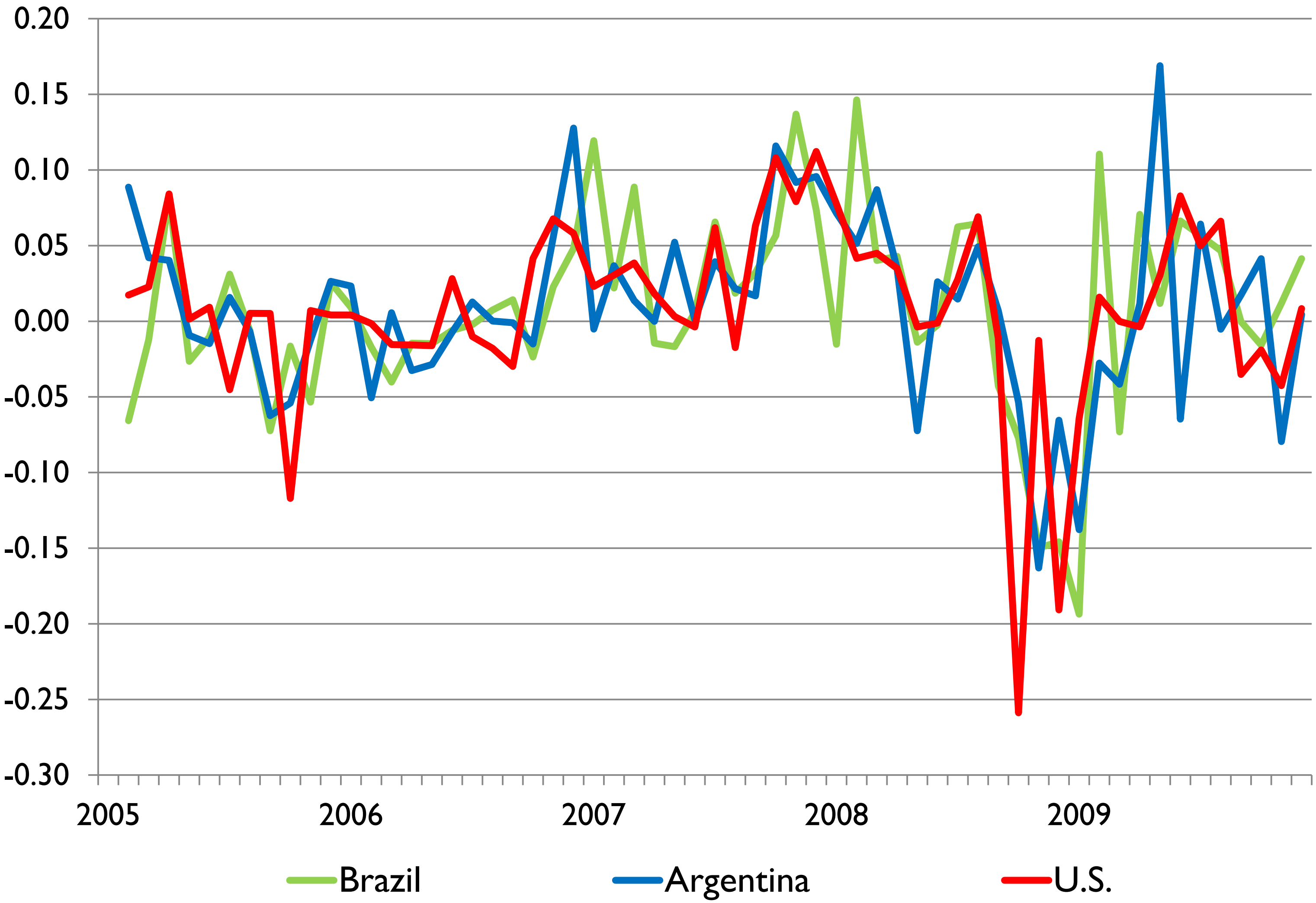
China's Soybean Prices by Exporter: Jan. 2005-Dec. 2009
(log differences)



Source: World Trade Atlas Database

Import allocation as the first stage of an expected utility problem…

R : net revenue from outputs and domestic resources.

p_i and q_i denote the price and quantity of a commodity from the ith country ($i = 1, 2 \ldots n$).

The optimal allocation of **q** is the solution to the following:

$$\underset{\mathbf{q}}{\text{Max}}\, U\left[R - E(\mathbf{p}'\mathbf{q}), V(\mathbf{p}'\mathbf{q})\right]$$
$$\text{s.t. } Q = \boldsymbol{\iota}'\mathbf{q},\ \mathbf{q} \geq \mathbf{0}$$

The Lagrangian for the utility maximization problem is

$$\Lambda = U(R - \tilde{\mathbf{p}}'\mathbf{q}, \mathbf{q}'\boldsymbol{\Omega}\mathbf{q}) + \lambda(Q - \boldsymbol{\iota}'\mathbf{q})$$

The first order condition with respect to the ith import (q_i) is

$$\Lambda_i = \frac{\partial \Lambda}{\partial q_i} = -U_1 p_i + 2U_2\left(q_i\sigma_i^2 + \sum_{j \neq i} q_j \sigma_{ij}\right) - \lambda = 0$$

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Import allocation equation in general form…

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

$$q_i^* = q_i(Q, \tilde{p}_1, \tilde{p}_2, \dots, \tilde{p}_n, \sigma_1^2, \sigma_2^2, \dots, \sigma_n^2)$$

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.

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

Solving for the price and variance effects…

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

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

$$\frac{\partial \log q_i}{\partial \log \sigma_j^2} = -u^{ij}\phi_{jj} - V_j \sum_{j=1}^{n} u^{ij}\psi_{2j} + \frac{\partial \log q_i}{\partial \log Q}\frac{\partial \log Q}{\partial \log \lambda}\frac{\partial \log \lambda}{\partial \log \sigma_j^2}$$

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Differential Import Allocation (DIA) Model

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

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

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

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

$\theta_i = \partial q_i / \partial Q$

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

- The average and marginal share (s_i and θ_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.

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Differential Import Allocation (DIA) Model

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

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: $\nu_{ij} = 0 \forall ij$

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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.

- Monthly data are used for estimation (January 2005–December 2009) (World Trade Atlas).

- 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.

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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.

$$\Delta \mathbf{p}_t = \boldsymbol{\alpha}_0 + \mathbf{A}_1 \Delta \mathbf{p}_{t-1} + \mathbf{A}_2 \Delta \mathbf{z}_t + \mathbf{A}_3 \Delta \mathbf{z}_{t-1} + \boldsymbol{\varepsilon}_t$$

$$\hat{\boldsymbol{\Omega}}_t = \mathbf{B}_0 + \mathbf{B}_1 \boldsymbol{\varepsilon}_{t-1} \boldsymbol{\varepsilon}'_{t-1} \mathbf{B}_1 + \mathbf{B}_2 \boldsymbol{\varepsilon}_{t-2} \boldsymbol{\varepsilon}'_{t-2} \mathbf{B}_2$$

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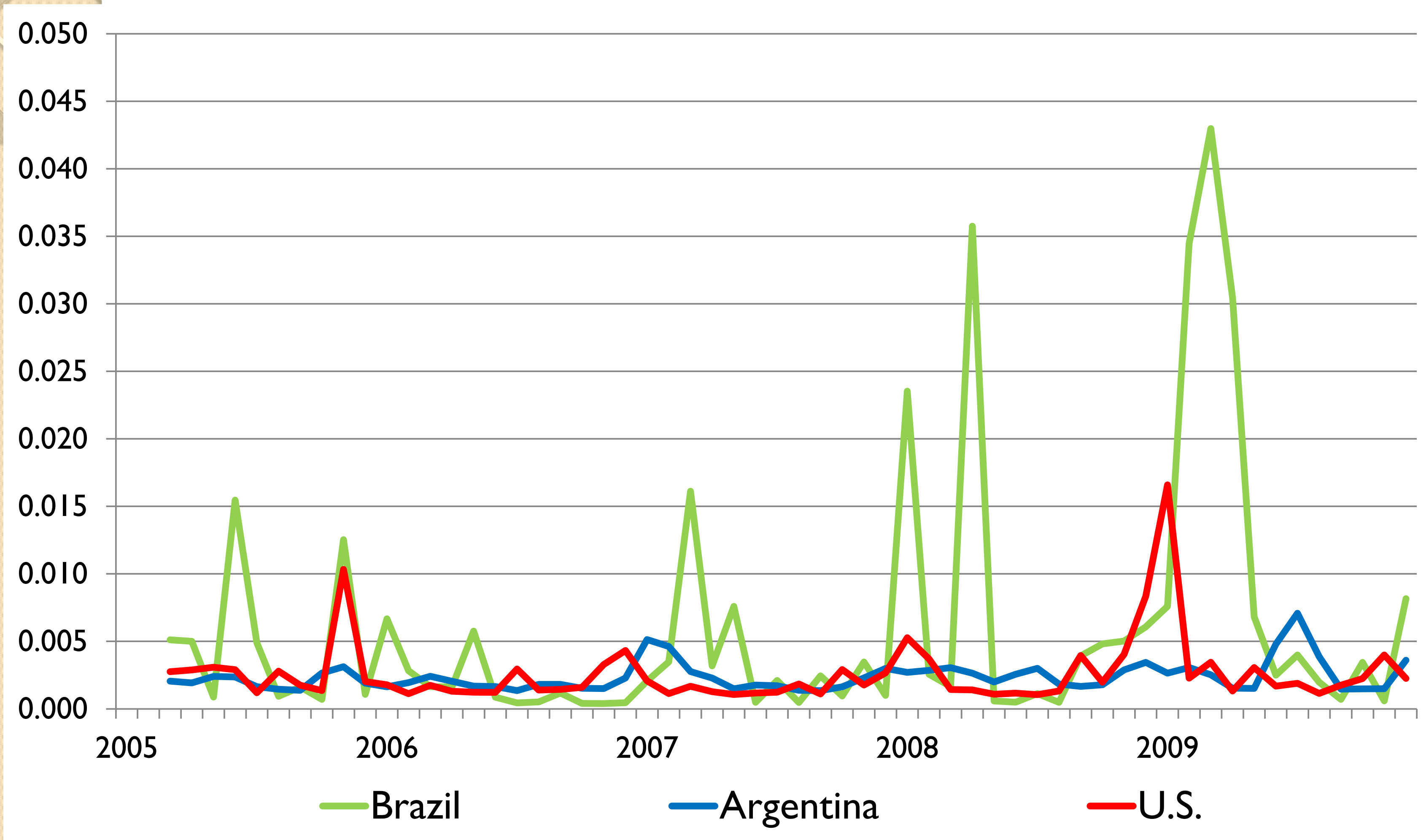
Multivariate ARCH(2) Estimates: March 2005-Dec. 2009



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Likelihood ratio tests results

Models	Log-likelihood Value	LR Statistic	Restricted parameters	P-value
Unrestricted	96.116			
Homogeneity	92.946	6.339	2	0.042
Symmetry	88.730	8.432	1	0.004
Own-risk*	76.771	32.351	4	0.000
Risk Neutrality*	73.763	38.366	6	0.000

* Compare to the symmetry constrained model.

Import demand estimates for China's soybean imports

Country	Marginal share θ_i	Price effects π_{ij}			Risk effects ν_{ij}		
		Brazil	Argentina	U.S.	Brazil	Argentina	U.S.
Brazil	0.487	-0.027	0.064	-0.037	-0.034	0.022	-0.042
	(0.057)[a]	(0.007)[a]	(0.015)[a]	(0.020)	(0.012)[a]	(0.036)	(0.022)[b]
Argentina	0.238	0.014	-0.154	0.140	0.037	-0.070	0.061
	(0.046)[a]	(0.006)[b]	(0.012)[a]	(0.016)[a]	(0.010)[a]	(0.029)[b]	(0.017)[a]
U.S.	0.276	0.013	0.090	-0.103	-0.003	0.048	-0.018
	(0.026)[a]	(0.009)	(0.019)[a]	(0.024)[a]	(0.015)	(0.044)	(0.027)

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

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

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

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Import demand elasticities for China's soybean imports

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

Asymptotic standard errors are in parentheses.

* denotes a significance level ≤ 0.05.

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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.