Strategic Trade Policies in the U.S. Orange Juice Market: Competition between Florida and São Paulo

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1 Introduction

Orange juice production is highly concentrated both geographically and economically. Florida is the largest orange juice producing state in the United States and similarly the state of São Paulo is in Brazil. Florida and São Paulo orange juice processors control an average of 89% of the U.S. market, while São Paulo processors supply an average of 84% of the European market (Foreign Agricultural Service, 2012). Florida supplied an average of 92% of all U.S. processed oranges for the period 1986-2010 (Economic Research Service, 2012b). For the same period, an average of 23% of the total U.S. orange juice supply was imported, and São Paulo shipped 74% of all U.S. imports (Food and Agricultural Organization, 2012).

Orange juice production in Florida and São Paulo is highly concentrated. According to Florida Department of Agriculture and Consumer Services (2012), the number of orange processors in Florida declined from 45 in 1997 to 16 in 2010.[1] In São Paulo, four firms produced about 85% of the total Brazilian supply during the 2004/2005 season (U.S. International Trade Commission, 2006). The high concentration of processors in Florida and São Paulo makes it conducive for these processors to exercise market power by engaging in oligopolistic competition. Hart (2004) reports that orange juice processors in both countries have high bargaining power with their buyers and exert oligopoly power. But, oligopsony power by juice demanders is unlikely because of the lack of concentration or collusion among buyers. Orange growers are likely to operate under perfect competition because of the large number of growers[2] and intense rivalry, which results in minimal collective bargaining power with processors. Thus, orange juice processors are the only group in the supply chain with a potential to influence the U.S. or European orange juice price and extract oligopoly rents.

São Paulo and Florida are the number one and two orange juice producing states, while the United States and Europe rank first and second in terms of per capita orange juice consumption in

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[1]Orange juice processors are a subset of orange processors. According to Florida Department of Agriculture and Consumer Services (2012), there were 35 orange processors in Florida during the 2000/2001 season, and Spreen and Fernandes (2000) reports a total of 18 orange juice processors in Florida during the 2000/2001 season.

[2]Wang et al. (2006) reports that there were over 7,500 orange farms in Florida in 2002.

the world (Hart, 2004). Even though Florida produces large volumes of orange juice, because of the high level of U.S. consumption, the United States exports only 6% of its total production (Economic Research Service, 2012b). Consequently, the European orange juice market is dominated by São Paulo orange juice producers. Brazil exports 99% of its processed oranges because Brazilians mainly drink fresh squeezed orange juice (Hart, 2004; Mendes, 2011). Europe produces a relatively small amount of orange juice and accounts for about 80% of total world imports.

The U.S. and European orange juice markets are protected by tariffs. The U.S. citrus juice tariff has protected juice producers in Florida from overseas competition since 1930. In the United States, the most-favored-nation applied tariff for frozen-concentrated orange juice (FCOJ) was $0.3501 per SSE (single strength equivalent) gallon until 1994 when the Uruguay Round of the General Agreement on Tariffs and Trade mandated that the tariff decrease by 15% to $0.2971 per SSE gallon by 2000 (Brown et al., 2004; Spreen et al., 2003). Europe imposed an ad valorem tariff of 19% until the Uruguay Round, after which the tariff was reduced to 15.20% by 2000.

The Summit of the Americas in 1994 was the first meeting where 34 "democracies" of the Western Hemisphere discussed the Free Trade Area of the Americas (FTAA) with the goal of liberalizing trade among member nations. Florida orange juice processors will face even more competition under the FTAA because the U.S. orange juice tariff will be subject to reduction or elimination. Supporters of free trade argued that removal of the tariff will provide U.S. consumers with the lowest cost orange juice possible (LaVigne, 2003). However, proponents of the tariff contend that without the tariff, Brazilian processors, which are already highly concentrated, will control an even larger market share in the United States. This could lead to high market power and prices for U.S. consumers. However, so far no agreement on FTAA has been reached, and the U.S. tariff has not changed since 2000 (World Trade Organization, 2012).

Spreen et al. (2003) developed a spatial equilibrium model of processed oranges and estimated the demand and new planting of orange trees to project the impact of the elimination of the U.S. orange juice tariff on U.S. production, prices, and imports. Their results showed that the domestic FCOJ price declined by $0.22 per SSE gallon when the U.S. tariff was removed. Brown

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et al. (2004) also examined the impact of the removal of the U.S. tariff on FCOJ prices. Their results revealed that while unilateral elimination of the U.S. tariff resulted in a reduction of the U.S. FCOJ price by $0.22 per SSE gallon, simultaneous elimination of the U.S., European, and Japanese tariff reduced the U.S. price by only $0.13 per SSE gallon. Brown (2010) estimated the European demand for FCOJ to gain insight into the price response in Europe and found the ordinary least squares and instrumental variable estimates of demand elasticities to be -0.45 and -0.69, respectively.

Wang et al. (2006) analyzed the impact of a supply shock due to weather on competition between oligopolistic firms in the U.S. orange juice market. They estimated market power using the grower's price and include quantity, an indicator variable for crop freezes, and a trend in their marginal cost function, and found that a supply shock decreases the market power of orange juice processors even as the price increases.

In this study, given the dominance of Florida and São Paulo, we analyze the oligopolistic competition and market power of FCOJ processors of these states using the U.S. national FCOJ retail price and European FCOJ price. We focus on FCOJ because the majority of trade is in the form FCOJ rather than not-from-concentrate orange juice due to the convenience of international shipping, and time series data for the national price of FCOJ is readily available making econometric estimation possible.[3]

Strategic trade theory analyzes policies implemented by governments to improve their firms' (or industries') position in international markets operating under imperfect competition.[4] Brander and Spencer (1985) in their seminal work on strategic trade theory showed that unlike under perfect competition, an export subsidy can result in a net welfare gain for the home country at the expense of the competitor's welfare due to rent shifting from the foreign to the home industry. We follow this literature to theoretically analyze the U.S. and European FCOJ markets under imperfect competition. Econometric estimation of market power gained momentum in the 1980s

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[3]An extensive data series for the national price for fresh orange juice is not avaliable.

[4]Strategic trade policy is part of the new trade theory developed in the late 1970s and 1980s. This theory integrates increasing returns to scale, Dixit-Stiglitz preferences, and imperfect competition into models of international trade to show countries with similar factor endownments and comparative advantages engage in trade.

with the development of the New Empirical Industrial Organization (NEIO) literature. Identification issues related to estimating market power is a central focus of the NEIO literature.[5] We draw on several empirical studies that have estimated industry-level market power in an international setting (Yerger, 1996; Lavoie, 2005) for our empirical work.

The specific objectives of this study are to 1) develop a strategic trade model to analyze the oligopolistic competition of Florida and São Paulo FCOJ processors, 2) derive analytical results to theoretically examine the effect of a change in the U.S. and European tariffs on the FCOJ market in the United States and Europe, 3) specify and estimate an econometric model based on the strategic trade model and compute the degree of market power exerted by Florida and São Paulo FCOJ processors, and 4) simulate the effect of exogenous changes in the U.S. and European tariffs on prices, sales, and welfare in the United States, São Paulo, and Europe.

The next section develops the strategic trade model and presents the analytical results for a change in the U.S. and European tariffs. Section 3 derives the empirical specification, describes the data and sources, explains the results of the econometric estimation, discusses the market power in the United States and Europe using estimated Lerner Indices, and presents the results of the simulation analysis. Section 4 summarizes the major findings of the study.

2 Theoretical Analysis

Based on the above FCOJ market description, we formulate a strategic trade model and derive the comparative statics and welfare results of a change in the U.S. and European tariffs.

2.1 Strategic Trade Model

Consider the U.S. and European FCOJ markets where Florida processors sell in the U.S. market and São Paulo processors export to both the United States and Europe. Florida and São Paulo processors face downward sloping demand functions, allowing for the potential to exert market power. São Paulo firms have a distinct cost advantage due to lower input prices, but incur transport costs and face tariffs to export to the United States and Europe. The U.S. and European governments impose tariffs on FCOJ imports. The profit function for the representative FCOJ

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[5]See Bresnahan (1989) for a review of this literature.

processor in Florida is[6]

$$(1) \qquad \pi^f = p^u\left(q^u\right)q^f - C^f\left(q^f\right) - F^f$$

where p^u is the price of FCOJ in the United States, $p^u\left(q^u\right)$ is the U.S. demand for FCOJ, $q^u = q^f + q^{su}$ is total quantity of FCOJ sold in the United States, q^f is the quantity of FCOJ sold by Florida processors, q^{su} is the quantity of FCOJ sold in the United States by São Paulo processors, and $C^f\left(\cdot\right)$ and F^f are the variable and fixed costs of production in Florida. The profit function for the representative processor in São Paulo is

$$(2) \qquad \pi^s = \frac{p^u\left(q^u\right)}{\left(1+\tau^u\right)}q^{su} + \frac{p^e\left(q^{se}\right)}{\left(1+\tau^e\right)}q^{se} - C^s\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e}\right) - F^s$$

where τ^i $(i = u, e)$ is the tariff on FCOJ entering the United States and Europe, p^e is the price of FCOJ in Europe, $p^e\left(q^{se}\right)$ is the European demand for FCOJ produced in São Paulo, q^{se} is the total quantity of FCOJ sold in Europe by São Paulo processors, $C^s\left(\cdot\right)$ and F^s are the variable and fixed costs of production in São Paulo, and g^i $(i = u, e)$ is the iceberg transport cost of shipping FCOJ from Brazil to the United States or Europe.

The profit functions are differentiated with respect to q^f, q^{su}, and q^{se} to derive the first-order conditions that implicitly determine the reaction or best-response functions as

$$(3) \qquad \pi^f_{q^f} = \frac{\partial p^u}{\partial q^f}q^f + p^u - \frac{\partial C^f}{\partial q^f} = 0$$

$$(4) \qquad \pi^s_{q^{su}} = \frac{1}{\left(1+\tau^u\right)}\left(\frac{\partial p^u}{\partial q^{su}}q^{su} + p^u\right) - \frac{\partial C^s}{\partial q^{su}} = 0$$

$$(5) \qquad \pi^s_{q^{se}} = \frac{1}{\left(1+\tau^e\right)}\left(\frac{\partial p^{se}}{\partial q^{se}}q^{se} + p^e\right) - \frac{\partial C^s}{\partial q^{se}} = 0$$

The reaction function imply a unique solution if they are downward sloping and satisfy the second-order conditions.

2.2 Tariff Analysis

As elaborated in the introduction, the Uruguay Round agreement reduced the U.S. and European tariff. Furthermore, if the FTAA or the Doha round are finalized, FCOJ tariffs could be further

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[6]This is an industry-level analysis, but a firm-level oligopolistic model that is aggregated to describe average firm behavior is at the root of the analysis.

lowered. Consequently, it is worth examining the impacts of a U.S. and European tariff reduction on FCOJ markets and welfare.

To analyze the effect of changes in U.S. and European tariffs on Florida and São Paulo FCOJ sales, we totally differentiate the reaction functions (3)-(5) and represent them in matrix form of $Ax = d$:

$$
(6) \quad \begin{bmatrix} \pi^f_{q^f q^f} & \pi^f_{q^f q^{su}} & 0 \\ \pi^s_{q^{su} q^f} & \pi^s_{q^{su} q^{su}} & \pi^s_{q^{su} q^{se}} \\ 0 & \pi^s_{q^{se} q^{su}} & \pi^s_{q^{se} q^{se}} \end{bmatrix} \begin{bmatrix} dq^f \\ dq^{su} \\ dq^{se} \end{bmatrix} = - \begin{bmatrix} \pi^f_{q^f \tau^u} d\tau^u + \pi^f_{q^f \tau^e} d\tau^e \\ \pi^s_{q^{su} \tau^u} d\tau^u + \pi^s_{q^{su} \tau^e} d\tau^e \\ \pi^s_{q^{se} \tau^u} d\tau^u + \pi^s_{q^{se} \tau^e} d\tau^e \end{bmatrix}.
$$

To study the welfare impacts of tariff changes, we define the welfare functions for the United States, São Paulo, and Europe. In the United States, FCOJ is produced in Florida, consumed nation wide, and tariff revenues are collected by the government. Thus U.S. welfare consists of profits, consumer surplus, and tariff revenues:

$$
(7) \qquad W^u \left(q^u, q^{su}; \tau^u, \tau^e \right) = \pi^f + \left\{ \int p^u \left(q^u \right) dq^u - p^u \left(q^u \right) q^u \right\} + \tau^u q^{su}.
$$

In São Paulo, because all FCOJ is exported and there is no consumption, welfare consists of only profits from sales to the United States and Europe:

$$
(8) \qquad W^s \left(q^u, q^{su}, q^{se}; \tau^u, \tau^e \right) = \pi^s.
$$

In Europe, because there is no production, FCOJ consumption is only from imports, and tariff revenues are collected by the government, welfare consists of consumer surplus and tariff revenues:

$$
(9) \qquad W^e \left(q^{se}; \tau^u, \tau^e \right) = \left\{ \int p^e \left(q^{se} \right) dq^{se} - p^e \left(q^{se} \right) q^{se} \right\} + p^e \left(q^{se} \right) \tau^e q^{se}.
$$

2.2.1 Effects of U.S. Tariff

By applying Cramer's rule to (6), the results for a change in the U.S. tariff, τ^u, are obtained by (see Appendix 4 for the derivation)[7]

$$\text{(10)} \qquad \frac{dq^{su}}{d\tau^u} = \frac{1}{|A|}\pi^f_{q^f q^f}\pi^s_{q^{se}q^{se}}\pi^s_{q^{su}\tau^u} < 0$$

$$\text{(11)} \qquad \frac{dq^{se}}{d\tau^u} = -\frac{1}{|A|}\pi^f_{q^f q^f}\pi^s_{q^{se}q^{su}}\pi^s_{q^{su}\tau^u} > 0$$

$$\text{(12)} \qquad \frac{dq^f}{d\tau^u} = -\frac{1}{|A|}\pi^f_{q^f q^{su}}\pi^s_{q^{se}q^{se}}\pi^s_{q^{su}\tau^u} > 0.$$

A reduction in the U.S. tariff decreases the price of São Paulo's FCOJ in the U.S. market. As a result, exports from São Paulo to the United States increase (equation 10) at the expense of their exports to Europe equation (11). The higher imports from São Paulo displaces Florida's FCOJ sales in the U.S. market equation (12). The effect of a U.S. tariff reduction on total U.S. sales is determined by adding (10) and (12): $\frac{dq^u}{d\tau^u} = \frac{dq^{su}}{d\tau^u} + \frac{dq^f}{d\tau^u}$, which is indeterminate, but q^u will likely increase because the direct effect $\left(\frac{dq^{su}}{d\tau^u}\right)$ will dominate the indirect effect $\left(\frac{dq^f}{d\tau^u}\right)$.

Welfare results for the tariff analysis consists of producer surplus (PS), consumer surplus (CS), and tariff revenue (TR) effects, and the signs in the parentheses for these three effects in the following equations indicate the direction of the changes. To examine the effect of U.S. tariff reduction on U.S. welfare, we totally differentiate 7 (see appendix 4 for the derivation) to obtain

$$\frac{dW^u}{d\tau^u} = \overbrace{q^f\frac{\partial p^u}{\partial q^u}\frac{\partial q^{su}}{\partial \tau^u}}^{PS\ (+)} \overbrace{-q^u\frac{\partial p^u}{\partial q^u}\frac{\partial q^u}{\partial \tau^u}}^{CS\ (-)} + \overbrace{\frac{\partial q^{su}}{\partial \tau^u}\tau^u + q^{su}}^{TR\ (?)}.$$

As Florida loses market share to São Paulo, Florida's producer surplus declines. U.S. consumers benefit from lower prices and higher consumption resulting from increased sales in the United States. Changes in tariff revenues could be positive or negative depending on the location of the initial tariff on the Laffer curve. Consequently, the net effect of a U.S. tariff reduction on U.S. welfare is ambiguous because of the conflicting signs of the three components. However, U.S.

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[7]The determinant of A is given by
$|A| = \pi^f_{q^f q^f}\pi^s_{q^{su}q^{su}}\pi^s_{q^{se}q^{se}} - \pi^f_{q^f q^f}\pi^s_{q^{su}q^{se}}\pi^s_{q^{se}q^{su}} - \pi^f_{q^f q^{su}}\pi^s_{q^{su}q^f}\pi^s_{q^{se}q^{se}}$, and is positive for plausible supply and demand functions.

welfare is likely to increase because the gain in consumer surplus can exceed the loss in produce surplus and any tariff revenue losses.

To analyze a change in São Paulo's welfare arising from a decrease in the U.S. tariff, we totally differentiate (8) to get

$$\frac{dW^s}{d\tau^u} = \overbrace{\frac{q^{su}}{(1+\tau^u)}\frac{\partial p^u}{\partial q^u}\frac{\partial q^f}{\partial \tau^u} - \frac{p^u q^{su}}{(1+\tau^u)^2}}^{PS\ (-)} < 0.$$

As São Paulo exporters capture U.S. market share from Florida, their producer surplus rises.

To investigate the European welfare change arising from a lower U.S. tariff, we totally differentiate (9) to obtain

$$\frac{dW^e}{d\tau^u} = \overbrace{-q^{se}\frac{\partial p^e}{\partial q^{se}}\frac{\partial q^{se}}{\partial \tau^u}}^{CS\ (+)} + \overbrace{\left(q^{se}\frac{\partial p^e}{\partial q^{se}} + p^e\right)\tau^e\frac{\partial q^{se}}{\partial \tau^u}}^{TR\ (+)} > 0.$$

Because São Paulo exports more to the United States, its exports to Europe decline, leading to a higher price, less consumption, and a decline in consumer surplus in Europe. Fewer imports by Europe also contracts tariff revenues (note that only imports decline and τ^e is constant). Consequently, Europe experiences welfare reduction.

2.2.2 Effects of European Tariff

The effects of a change in the European tariff , τ^e, on quantities sold by Florida and São Paulo producers are given by

$$(13) \qquad \frac{dq^{se}}{d\tau^e} = -\frac{1}{|A|}\left(\pi^f_{q^f q^{su}}\pi^s_{q^{su} q^f}\pi^s_{q^{se}\tau^e} + \pi^f_{q^f q^f}\pi^s_{q^{su} q^{su}}\pi^s_{q^{se}\tau^e}\right) < 0$$

$$(14) \qquad \frac{dq^{su}}{d\tau^e} = -\frac{1}{|A|}\pi^f_{q^f q^f}\pi^s_{q^{su} q^{se}}\pi^s_{q^{se}\tau^e} > 0$$

$$(15) \qquad \frac{dq^f}{d\tau^e} = \frac{1}{|A|}\pi^f_{q^f q^{su}}\pi^s_{q^{su} q^{se}}\pi^s_{q^{se}\tau^e} < 0.$$

A decrease in the European tariff lowers the price of São Paulo's FCOJ in Europe. Consequently, São Paulo exporters reallocate their exports from the United States to Europe (equation 14 and 13). As exports from São Paulo to the United States decrease, Florida's FCOJ sales in the U.S. market expands (equation 15). To examine the effect of European tariff reduction on total sales in the

United States, we add (14) and (15): $\frac{dq^u}{d\tau^e} = \frac{dq^{su}}{d\tau^e} + \frac{dq^f}{d\tau^e}$. The net effect of q^u is ambiguous, but the direct effect $\left(\frac{dq^{su}}{d\tau^e}\right)$ is likely to dominate the indirect effect $\left(\frac{dq^f}{d\tau^e}\right)$, leading to a decline in the quantity sold in the United States.

To determine the effect of a reduction in the European tariff on U.S. welfare, we totally differentiate (7) to get

$$\frac{dW^u}{d\tau^e} = \overbrace{q^f \frac{\partial p^u}{\partial q^u}\frac{\partial q^{su}}{\partial \tau^e}}^{PS\ (-)} \overbrace{-q^u \frac{\partial p^u}{\partial q^u}\frac{\partial q^u}{\partial \tau^e}}^{CS\ (+)} \overbrace{+\tau^u \frac{\partial q^{su}}{\partial \tau^e}}^{TR\ (+)}.$$

As São Paulo diverts its exports from the United States to Europe, Florida processors capture a higher share of the U.S. market and their producer surplus rises. As imports from São Paulo fall, total sales in the United States decline and the FCOJ price goes up, resulting in lower consumer surplus. Lower U.S. imports also causes tariff revenues to fall. The net change in U.S. welfare is ambiguous, but it will likely decline as consumer surplus and tariff revenue losses can offset the producer surplus gain.

To ascertain the change in São Paulo's welfare arising from a decrease in the European tariff, we totally differentiate (8) to obtain

$$\frac{dW^s}{d\tau^e} = \overbrace{\overbrace{\frac{q^{su}}{(1+\tau^u)}\frac{\partial p^u}{\partial q^u}\frac{\partial q^f}{\partial \tau^e}}^{(+)} \overbrace{-\frac{p^e q^{se}}{(1+\tau^e)^2}}^{(-)}}^{PS\ (?)}.$$

As São Paulo reallocates its exports from the United States to Europe, profits from U.S. exports decline (first term on the right-hand-side), but profits from European exports increase (second term on the right-hand-side). As a result, the net effect on producer surplus is ambiguous; however, welfare will likely increase because higher profits from the European market (direct effect) can dominate the reduction in profits from the U.S. market (indirect effect). Note that because there is no FCOJ production in Europe, all the profit changes accrue to São Paulo and there is no diversion of profits from Europe to São Paulo.

To analyze the change in European welfare arising from a reduction in the European tariff,

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we totally differentiate (9) to get

$$\frac{dW^e}{d\tau^e} = \overbrace{-q^{se}\frac{\partial p^e}{\partial q^{se}}\frac{\partial q^{se}}{\partial \tau^e}}^{CS\ (-)} + \overbrace{\left(q^{se}\frac{\partial p^e}{\partial q^{se}} + p^e\right)\tau^e\frac{\partial q^{se}}{\partial \tau^e}}^{TR\ (?)} + p^e q^{se}.$$

As European imports rise, the FCOJ price in Europe declines and consumption expands, resulting in a gain in consumer surplus. Tariff revenues can increase or decrease depending on the initial location of the tariff on the Laffer curve. Consequently, the change in European welfare is indeterminate, but it will likely increase because the consumer surplus gain can outweigh the tariff revenue effect (if it is negative).

3   Empirical Analysis

In this section, we derive the econometric model based on the strategic trade model, discuss data and sources, present the estimation results, calculate the Lerner index, and present the simulation analysis and results.

3.1   Econometric Model

In the U.S. FCOJ market, other countries such as Mexico, Costa Rica, and Belize also supply FCOJ. However, their market shares relative to Florida and São Paulo are small, and we considered them exogenous in the model. Total sales in the United States are defined as $q^u = q^f + q^{su} + q^o$, where q^o is the quantity sold by processors other than Florida and São Paulo processors.[8]

We specify the econometric model by rewriting the first-order conditions (equations 3-5) as

$$(16) \qquad\qquad p^u \;=\; \frac{\partial C^f}{\partial q^f} + \theta^f \varepsilon^u p^u$$

$$(17) \qquad\qquad p^u \;=\; (1 + \tau^u)\frac{\partial C^s}{\partial q^{su}} + \theta^{su}\varepsilon^u p^u$$

$$(18) \qquad\qquad p^e \;=\; (1 + \tau^e)\frac{\partial C^s}{\partial q^{se}} + \theta^{se}\varepsilon^e p^e$$

where $\theta^f = \dfrac{\partial q^u}{\partial q^f}\dfrac{q^f}{q^u}$ is the conjectural elasticity for Florida processors, $\varepsilon^u = -\dfrac{\partial p^u}{\partial q^u}\dfrac{q^u}{p^u}$ is the U.S. price flexibility of demand, $\theta^{su} = \dfrac{\partial q^u}{\partial q^{su}}\dfrac{q^{su}}{q^u}$ is the conjectural elasticity for São Paulo processors

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[8]Combined FCOJ exports by Mexico, Costa Rica, and Belize are about 10% of total sales in the United States.

exporting to the United States, $\varepsilon^e = -\dfrac{\partial p^e}{\partial q^{se}}\dfrac{q^{se}}{p^e}$ is the European price flexibility of demand, and

$\theta^{se} = \dfrac{\partial q^{se}}{\partial q^{se}}\dfrac{q^{se}}{q^{se}}$ (note that θ^{se} is not necessarily equal to one because it is based on weighted average of each firm's conjectural elasticity; also see footnote 6 and Porter (1983), p. 304) is the conjectural elasticity for São Paulo processors exporting to Europe.

As seen by the second term on the right-hand-side of equations (16)-(18), an industry's ability to set price above marginal cost is driven by the interaction of the demand flexibilities and conjectural elasticities. Four cases are possible. First, under perfect collusion, orange juice processors act as a monopoly, and the conjectural variation and market share are one (e.g., $\partial q^u/\partial q^f = q^f/q^u = 1$). This implies that the conjectural elasticity is equal to one, and the markup is determined by the demand flexibilities. Second, if the orange juice processors operate under Cournot competition, the conjectural variation is equal to one (e.g., $\partial q^u/\partial q^f = 1$) and markup depends on the interaction of the demand flexibility and the representative firm's market share. Third, under a fully flexible market structure, market power is given by the conjectural elasticity weighted by the demand flexibility. Fourth, under perfect competition, the orange juice processors' market share is small enough so they cannot influence the FCOJ price. This implies that the markup is zero and price is equal to the marginal cost.

For estimable supply relations, we define marginal cost and demand functions and consider identification of demand and supply parameters and the conjectural elasticities. The marginal cost functions for Florida and São Paulo processors are defined as

$$(19) \qquad \frac{\partial C^f}{\partial q^f} = \beta_0^f + \beta_1^f q^f + \boldsymbol{\beta}^f \mathbf{x}^f$$

$$(20) \qquad \frac{\partial C^s}{\partial q^{su}} = \frac{1}{g^u}\left(\beta_0^{su} + \beta_1^{su}\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \boldsymbol{\beta}^{su}\mathbf{x}^s \right)$$

$$(21) \qquad \frac{\partial C^s}{\partial q^{se}} = \frac{1}{g^e}\left(\beta_0^{se} + \beta_1^{se}\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \boldsymbol{\beta}^{se}\mathbf{x}^s \right)$$

where β_j^is are marginal cost coefficients and $\mathbf{x}^i$s ($i = f, su$, and se) are supply shifters. The U.S.

and European demand functions are

$$(22) \qquad p^u = \alpha_0^u + \alpha_1^u q^u + \boldsymbol{\alpha}^u \mathbf{Z}^u$$

$$(23) \qquad p^e = \alpha_0^e + \alpha_1^e q^{se} + \boldsymbol{\alpha}^e \mathbf{Z}^e$$

where α_j^is are demand coefficients, and $\mathbf{Z}^i$s are U.S. and European demand shifters.

Using the first-order conditions (16)-(18), the marginal cost functions (19)-(21), and the demand flexibilities derived from the demand functions (22) and (23), the supply relations for Florida and São Paulo processors are represented as:

$$(24) \qquad p^u = \beta_0^f + \beta_1^f q^f + \boldsymbol{\beta}^f \mathbf{x}^f + \theta^f \alpha_1^u q^u$$

$$(25) \qquad p^u = \frac{(1+\tau^u)}{g^u} \left(\beta_0^{su} + \beta_1^{su} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \boldsymbol{\beta}^{su} \mathbf{x}^s \right) + \theta^{su} \alpha_1^u q^u$$

$$(26) \qquad p^e = \frac{(1+\tau^e)}{g^e} \left(\beta_0^{se} + \beta_1^{se} \left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e} \right) + \boldsymbol{\beta}^{se} \mathbf{x}^s \right) + \theta^{se} \alpha_1^e q^{se}.$$

The parameters in the U.S. demand function (22) are identified if the number of excluded exogenous variables from the demand function is greater than or equal to the number of endogenous variables p^u and q^u. The parameters in the U.S. supply relation (24), including $\theta^f \alpha_1^u$ are identified if the number of excluded exogenous variables is greater than or equal to the number of endogenous variables p^u, q^u, q^f. Estimation of the system of equations will yield an estimate for α_1^u and a combined estimate for $\theta^f \alpha_1^u$. Using the estimate of α_1^u, the conjectural elasticity θ^f can be identified from the estimate of $\theta^f \alpha_1^u$. Applying analogous identification rule to the European demand function (23) and São Paulo's supply relations for the United States (25) and Europe (26), we can confirm that the demand and supply parameters and the conjectural elasticities θ^{su} and θ^{se} can be uniquely identified and thus estimated.

3.2 Data

The data set consists of annual observations for the period 1986-2009. The total supply, imports, and exports for the U.S. orange juice industry was collected from Economic Research Service (2012a). From the domestic supply for all orange juice, we obtained the domestic FCOJ supply, which is decomposed into the Florida FCOJ supply and other U.S. FCOJ supply using Tables C21

and C28-C30 from the Fruit and Tree Nut Yearbook of the Economic Research Service (2012b). Total U.S. orange juice imports were disaggregated to obtain total FCOJ imports, and the portion of FCOJ imports supplied by Brazil, using U.S. FCOJ import percentages by country from Food and Agricultural Organization (2012). The U.S. national price of FCOJ was constructed using two sources. First, for the years 1995-2009, we obtained the national FCOJ price from the Nielson report provided by the Florida Department of Citrus (2012). Next, we collected the U.S. FCOJ price index for the years 1986-2009 from the Bureau of Labor Statistics (2012). The correlation for the overlapping data from these two sources is 0.99. Therefore, the price index was used to backcast the Nielson price data for the period 1994-1986.

Price and quantity data for the European orange juice market are not available. We follow Brown et al. (2004) and Brown (2010) and use Brazil's export data to Europe because Brazil is the dominant FCOJ supplier in this market. Brazil's exports and unit price were obtained from Food and Agricultural Organization (2012).

For input price variables in Florida's and São Paulo's marginal cost functions, we used an aggregate cost measure comprised of labor, machinery, and other inputs. We constructed this aggregate measure using two data sources. Wade et al. (2001)[9] reports the data for the period 1986-2000 and the Foreign Agricultural Service (2012) has the data for 2004, and 2006-2009. We used a combination of forward and backcasting to fill the missing data for 2001-2003, and 2005. We included the producer price of oranges as the major input price in Florida's marginal cost equation, which was collected from Food and Agricultural Organization (2012). We were not able to use the producer price of oranges in São Paulo's marginal cost equation because of irreconcilable inconsistencies in their data. We added a trend variable in both marginal cost equations to account for technological advances. In São Paulo's marginal cost function, we included an indicator variable—one for the period 2004-2009 and zero otherwise—to account for discrepancies between the two data sources.

Demand shifters are income, population, and a substitute good. All prices and income

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[9]We thank Ron Muraro at the University of Florida for assistance with this data.

were converted into real terms using a GDP deflator to satisfy the homogeneity condition. Income, population, and the GDP deflators for the United States and Europe were collected from The World Bank (2012). In the U.S. demand function, the quantity of grapefruit juice sold, collected from Economic Research Service (2012a), was included as a substitute good. In the European demand function, the quantity of lemon juice, Brazil's second largest juice export to Europe, obtained from Food and Agricultural Organization (2012) was used as a substitute good. In the demand functions, a dummy variable—one for 2008 and 2009 and zero otherwise—interacts with income to account for the current economic turmoil.

We collect tariff data from the World Trade Organization (2012). As per the Uruguay Round agreement, the U.S. applied specific tariff is reduced from $0.3501 per SSE (single strength equivalent) gallon in 1994 to 0.2971 per SSE gallon by 2000, and the European applied ad valorem tariff is reduced from 19% in 2004 to 15.20% by 2000. We proxy transport costs from Brazil to the United States by taking the difference between the CIF and FOB fruit juice exports collected from the U.S. Census Bureau (2012). This transport cost data was used to construct the transport cost from São Paulo to Europe based on the distance between the latter two regions, which was obtained from "www.searates.com."

3.3 Estimation

The demand functions (22) and (23) and supply relations (24)-(26) are a system of 5 equations with 5 endogenous variables (p^u, p^e, q^{su}, q^{se}, q^f). We estimate the parameters using non-linear two-stage least square to account for the endogeneity, which allows for consistent estimates of the parameters, and nonlinearity in the system. The exogenous demand and marginal cost variables are used as instruments. To ensure that the objective function in the nonlinear estimation is at a global minimum, we considered a range of initial parameter values for estimating the coefficients.

As discussed in the Introduction section, the data for U.S. tariff is a specific tariff and for the European tariff is an ad valorem tariff, which are used for the empirical analysis. Since the transportation costs are available only on a per-unit basis (as opposed to an iceberg cost used in the analytical analysis), we use this per-unit cost for the analysis.

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Table 1 presents variable definitions. Table 2 presents the estimation results for the U.S. and European demand functions. The signs for the estimated coefficients are consistent with economic theory. In the demand for U.S. FCOJ, the estimated coefficients for the intercept, quantity, population, and an indicator variable interacting with real income are significant at the $\alpha = 5\%$ level or better. The flexibility of demand is -0.48 (or an elasticity of -2.08), which is higher than the elasticities estimated by Brown et al. (2004) at -0.70 and Davis et al. (2008) at -0.99. The negative coefficient estimate for population indicates that the demand for FCOJ has declined as the U.S. population has grown. This is consistent with the trend that consumers are substituting toward not-from-concentrate and fresh orange juice. In the U.S. market, the estimated income coefficient is positive indicating that as income increases, so does FCOJ consumption. The marginal impact of grapefruit juice is negative, implying that FCOJ and grapefruit juice are complements because an increase in grapefruit juice consumption will reduce the FCOJ price and increase FCOJ consumption. The estimated coefficient for the interaction of $D1$ with real income is positive, which indicates that the current economic crisis reinforced the income effect.

In the demand for European FCOJ, the estimated coefficients for the intercept, quantity, population, real income, cross-quantity of lemon juice, and dummy interaction with real income are significant at the $\alpha = 10\%$ level or better. The flexibility of demand is -0.80 (or an elasticity of -1.25). Brown et al. (2004) reports a price elasticity of demand for European FCOJ at -0.41, and Brown (2010) estimate the European price elasticity of demand at -0.45 and -0.68 for ordinary least squares and instrumental variable estimations, respectively. As in the U.S. market, the negative estimated coefficient for population implies the demand for FCOJ decreased in Europe as the population grew in this region. The coefficient for income is positive, implying that as income rises consumption of FCOJ increases. Lemon juice exports from São Paulo to Europe are complements with FCOJ because the estimated coefficient is negative, indicating that an increase in lemon juice quantity reduces FCOJ price and increases FCOJ consumption. The current economic crisis augments the income effect on FCOJ because the estimated coefficient on $D1$ interacting with real income is positive.

Table 1: Variable Definitions

Variable	Definition
q^u	Total U.S. sales of FCOJ, gallons of single strength equivalent (SSE)
q^f	Florida's FCOJ sales in the United States, gallons of SSE
q^{su}	São Paulo's sales of FCOJ in the United States, gallons of SSE
q^{se}	São Paulo's exports to Europe, gallons of SSE
$inputp^j$	Aggregate production cost of Florida's ($j = f$) and São Paulo's ($j = s$) processors, real cost \$/gal SSE
$prop^u$	U.S. producer price of oranges, real price \$/gal SSE
$tcost^i$	Transport cost for São Paulo to export to the U.S. ($i = u$) and Europe ($i = e$), index 1986=1
$trend$	trend
$D1$	Indicator variable: 1 for 2008 and 2009, zero otherwise
Pop^i	U.S. and European populations, in 100 millions
$RInc^i$	U.S. and European real income, in 100 billions
cq^u	U.S. grapefruit juice sales, gallons of SSE
cq^e	Brazilian exports of lemon juice to Europe, gallons of SSE
$D2$	Indicator variable: 1 for years 2004-2009, zero otherwise

Table 2: U.S. and European Demand Functions

Variable/Coefficients	United States ($i = u$)	Europe ($i = e$)
$intercept$	18.45 (0.000)	25.40 (0.000)
q^u	−0.21 (0.000)	—
q^{se}	—	−0.08 (0.001)
Pop^i	−5.24 (0.001)	−8.85 (0.000)
$RInc^i$	0.03 (0.129)	0.06 (0.005)
cq^i	−1.88 (0.215)	−3.98 (0.107)
$\left(cq^i\right)^2$	0.83 (0.219)	—
$D1 * RInc^i$	0.01 (0.001)	0.005 (0.073)

p-values are in parentheses

Table 3: Supply Relation for Florida Processors

Variable/Coefficients	Florida
$intercept^f$	1.100 (0.482)
q^f	1.290 (0.008)
$\left(q^f\right)^2$	-0.120 (0.008)
$inputp^f$	3.930 (0.201)
$prop^u$	0.005 (0.002)
$trend$	-0.060 (0.007)
θ^f	0.720 (0.019)

p-values are in parentheses.

Table 3 reports the estimated supply relation for Florida processors. The estimated coefficients are consistent with economic theory, and quantity supplied, price of oranges, trend, and conjectural elasticity are significant at the $\alpha = 5\%$ level or better. An increase in the quantity supplied, input prices, and the producer price for oranges increase the cost of production and thus the FCOJ price. The estimated coefficient for the trend variable is negative, implying that as technology advances production costs declined. The conjectural elasticity estimate is 0.72; this suggests that processors in Florida act as oligopolists.

Table 4 presents the estimated supply relation for São Paulo exports to the United States and Europe. The signs for the estimated coefficients are consistent with economic theory. For exports from São Paulo to the United States, the estimated coefficients for the intercept, input prices, trend, transport cost, and conjectural elasticity are all significant at the $\alpha = 5\%$ level or better. An increase in output and input prices will increase the marginal costs and thus the FCOJ price. The negative sign on the estimated coefficient for the trend variable indicates that marginal costs have decreased over time, which can be due to advances in technology. The estimated coefficient on the transport cost is positive, implying that higher shipping costs will raise the FCOJ price. The conjectural elasticity estimate is 1.07; while this is greater than the theoretical upper bound, it is not statistically different from one.

For exports from São Paulo to Europe, the estimated coefficients for the intercept, transport cost, and $D2$ are significant at the $\alpha = 5\%$ level or better. With higher quantities of output and input prices, the marginal costs increases, leading to an increase in the FCOJ price. The negative

Table 4: Supply Relations for Sao Paulo Processors

Variable/Coefficients	Exp to U.S. ($i = su$)	Exp to Europe. ($i = se$)
$intercept$	2.80 (0.089)	0.88 (0.030)
$(q^{su} + q^{se})$	0.01 (0.876)	0.02 (0.737)
$inputp^s$	123.58 (0.018)	8.59 (0.474)
$(inputp^s)^2$	-1706.71 (0.008)	-48.84 (0.489)
$(inputp^s)^3$	6831.12 (0.007)	—
$trend$	-0.04 (0.019)	-0.23 (0.156)
$tcost^i$	1.35 (0.000)	0.67 (0.000)
$D2$	—	-0.49 (0.000)
θ^f	1.07 (0.002)	1.06 (0.184)

p-values are in parentheses.

sign on the estimated coefficient for the trend variable suggests that technological advances in FCOJ production lowers the marginal cost and thus decreases the FCOJ price. As in the supply relation for exports to the United States, the positive estimate for transport costs means that an increase in the cost of shipping to Europe increases the FCOJ price. The conjectural elasticity estimate is 1.06. Again, even though the theoretical bound for this parameter estimate is one, it is not statistically different from one.

The conjectural elasticity estimates show that both the Florida and São Paulo processors act as oligopolists, but São Paulo processors are estimated to have greater market power. The conjectural elasticity estimates for São Paulo exporters to the United States and Europe are close to one. This suggests a high level of concentration and collusive behavior for FCOJ processing plants in São Paulo, which is consistent with industry evidence. As stated in the introduction, four firms in São Paulo were responsible for about 85% of total Brazilian production for the 2004/2005 season (U.S. International Trade Commission, 2006). In addition, Hart (2004) reports that São Paulo orange juice processors have a high level of bargaining power.

3.4 Lerner Index

The Lerner Index measures the markup of price over marginal cost and is equal to the conjectural elasticity times the demand flexibility. That is, an industry's ability to exercise oligopoly power and set price above its marginal costs depends on both the supply (conjectural elasticities) and

demand (price flexibilities) conditions. Rearranging the supply relations, equations 16-18, the Lerner Indices are expressed as

$$(27) \qquad \frac{p^u - \dfrac{\partial C^f}{\partial q^f}}{p^u} \;=\; \theta^f \varepsilon^u = 0.72 * 0.48 = 0.35$$

$$(28) \qquad \frac{p^u - (1 + \tau^u)\dfrac{\partial C^s}{\partial q^{su}}}{p^u} \;=\; \theta^{su} \varepsilon^u = 1.07 * 0.48 = 0.51$$

$$(29) \qquad \frac{p^e - (1 + \tau^e)\dfrac{\partial C^s}{\partial q^{se}}}{p^e} \;=\; \theta^{se} \varepsilon^e = 1.06 * 0.80 = 0.84$$

The results of the Lerner Index show that in the U.S. market, Florida (São Paulo) processors set their price above marginal cost by 35% (51%). Thus, both Florida and São Paulo processors earn oligopolistic rents, and São Paulo processors exert greater market power than Florida processors in the U.S. market. This is consistent with evidence that São Paulo processors are more concentrated (U.S. International Trade Commission, 2006; Florida Department of Agriculture and Consumer Services, 2012) and have lower production costs (Foreign Agricultural Service, 2012) than Florida processors. For the European market, the Lerner Index shows that São Paulo exporters set price 84% above their marginal cost. They are able to exert more market power in the European market than the U.S. market because the demand elasticity (i.e., $1/\varepsilon^i$, $i = u, e$) for São Paulo FCOJ in Europe is less elastic than that in the United States. The rationale for this result is that São Paulo is the largest supplier in Europe controlling 84% of the market, whereas in the U.S. market, São Paulo has to compete with Florida.

3.5 Simulation Results

The Free Trade Agreement of the Americas (FTAA) and the Doha round have been under negotiations since 1994 and 2000, respectively. If these negotiations are completed, the U.S. and European tariffs on FCOJ could again be reduced. In this section, we analyze the effect of a 25% reduction of the U.S. and European tariffs. For the baseline simulation, we implement the existing tariff and solve the parameterized econometric model as a system of 5 equations (22)-(26) in 5 endogenous price and quantity variables (p^u, p^e, q^f, q^{su}, and q^{se}). We also compute total

Table 5: Impacts of Tariff Reductions, Ave. 2006-09

	A 25% Tariff Reduction by	
Variables	U.S.	Europe
p^u (%)	−2.45	0.49
p^e (%)	6.21	−34.39
q^f (%)	−1.67	0.35
q^{su} (%)	36.16	−7.53
q^{se} (%)	−10.65	61.16
$q^u \left(= q^f + q^{su} + q^o \right)$ (%)	7.35	−1.50
Florida's market share in U.S. (%)	−8.27	1.88
São Paulo's market share U.S. (%)	26.58	−5.90
Change in Total U.S. Welfare (Million $)	25.44	−7.03
Change in Producer Surplus (Million $)	−41.52	8.22
Change in Consumer Surplus (Million $)	62.20	−12.18
Change in Tariff Revenue Change (Million $)	4.77	−3.07
Change in Total São Paulo Welfare (Million $)	12.76	19.78
Change in Producer Surplus (Million $)	12.76	19.78
Change in Total European Welfare (Million $)	−41.42	202.33
Change in Consumer Surplus (Million $)	−37.78	203.96
Change in Tariff Revenue (Million $)	−3.64	−1.63

sales in the United States as the sum of sales for Florida, São Paulo, and other region's FCOJ ($q^u = q^f + q^{su} + q^o$). We consider two alternate scenarios: a 25% reduction in the U.S. tariff and a 25% reduction in the European tariff. In both of these scenarios, tariffs are 25% less in each year for the period 2006-2009. We then take the average over this period for both the baseline and alternate scenarios, and compare the results for each of the alternate scenarios to those of the baseline to quantify the impacts of these two trade liberalization policies. Table 5 presents the simulation results, which are qualitatively consistent with the analytical results of section 2.2.

A 25% reduction in the U.S. tariff causes São Paulo exporters to divert their exports from Europe to the United States resulting in a 36.16% increase in their U.S. sales and a 10.65% decrease in their European sales. As a result of higher U.S. imports, Florida's sales are displaced by 1.67%. Consequently, São Paulo captures Florida's market share in the United States, leading to

an increase in São Paulo's market share by 26.58% and a decrease in Florida's by 8.27%. While the higher imports and lower Florida sales led to indeterminate analytical results for total U.S. sales, the quantitative results show that the direct (import) effect dominates the indirect (Florida) effect and total U.S. sales are 7.35% higher, which reduces the U.S. national price by 2.45%. Lower exports to Europe resulted in a 6.21% rise in their FCOJ price.

The welfare analysis of the U.S. tariff reduction shows that the gain in U.S. consumer surplus ($62.20 million) and tariff revenues ($4.77 million) outweigh the loss in producer surplus ($41.52 million), resulting in a net increase in U.S. welfare of $25.44 million. The increase in tariff revenues indicates that the United States is operating on the negatively sloped part of the Laffer curve, and thus a decline in the tariff causes the tariff revenues to rise. The higher sales in the U.S. market augments São Paulo's welfare, i.e., producer surplus, by $12.76 million. Fewer exports to Europe reduce the consumer surplus ($37.78 million) and tariff revenues ($3.64 million), leading to a net reduction in welfare of $41.42 million. The European tariff revenues decrease because FCOJ imports declines but the European tariff rate remains constant in this scenario.

A 25% decrease in the European tariff results in a reallocation of São Paulo's exports from the United States to Europe, leading to a 61.16% increase in exports to Europe and a 7.53% decrease in exports to the United States, which causes Florida's sales in the United States to expand by 0.35%. Because of this reallocation, Florida's market share in the United States rises by 1.88%, while São Paulo's market share falls by 5.90%. Higher European imports depresses their FCOJ price by 34.39%. In the theoretical analysis, the lower imports and higher Florida sales indicate ambiguous comparative static results for total U.S. sales, but the simulation results show that the direct effect outweighs the indirect effect and total U.S. sales fall by 1.50%, which raises the U.S. national price by 0.49%.

The welfare analysis indicates that as a result of this European tariff reduction, the gain in U.S. producer surplus ($8.22 million) is insufficient to compensate for the reduction in consumer surplus ($12.18 million) and tariff revenues ($3.07 million), resulting in a net U.S. welfare loss of $7.03 million. Higher sales in the European market lead to a net increase in São Paulo's welfare of

$19.78 million. The benefit to European consumers ($203.96 million) from higher imports is more than the loss in tariff revenues ($1.63 million) leading to a net European welfare gain of $202.33 million. The loss of tariff revenues suggest that Europe is functioning on the positively sloped part of the Laffer curve and as the tariff declines, tariff revenues increase.

Spreen et al. (2003) developed a spatial equilibrium model with implicit supply functions to forecast the behavior of the orange juice industry. They simulated two scenarios for out-of-sample projections. In the first scenario, both U.S. and European tariffs are phased out over a 15 year period beginning in 2002. Their results showed minimal effects on both orange juice prices and sales in both the United States and Europe. In the second scenario, both tariffs are eliminated in 2002. In this case, the U.S. FCOJ price falls by 20%, which causes U.S. consumption to increase by 8%. The European price rises by 13% which resulted in a 9% decline in consumption. Using a demand model, Brown et al. (2004) examined the effect of tariff elimination on prices and found results similar to those of Spreen et al. (2003).

Our simulation analysis differ from Spreen et al. (2003) in three notable ways. First, Spreen et al. (2003) applied a dynamic spatial-equilibrium model under prefect competition, whereas our model is a static strategic trade model based on imperfect competition. Second, Spreen et al. (2003) estimated demand equations for the United States, Europe, and Japan and supply functions for Florida and São Paulo individually, whereas we estimate demand equations for the United States and Europe and supply relations for Florida and São Paulo FCOJ processors simultaneously. Third, Spreen et al. (2003) used their model to project the impact of phasing out and elimination of the tariffs for an out-of-sample period, whereas we simulate the effect of a 25% tariff reduction over an in-sample period.

4   Conclusions

World orange juice production is highly concentrated in the states of Florida and São Paulo (Brazil), who supply about 85% of the total world supply. Also, these orange juice processing states supply an average of 89% of the total U.S. market, and São Paulo processors control about 84% of the total European market. Furthermore, the two largest orange juice consuming regions are the United

States and Europe.

We develop a strategic trade model based on the new trade theory. Because Florida and São Paulo processors are dominant in the FCOJ market, they face downward sloping demand functions. Our analytical results indicate that a reduction in the U.S. tariff causes São Paulo to reallocate its exports from Europe to the United States, which displaces FCOJ processing in Florida. A tariff reduction by Europe causes São Paulo to divert its exports from the United States to Europe. Florida captures the market lost by São Paulo in the United States. We also analyze the qualitative effects of these tariff reductions on the welfare of the United States, São Paulo, and Europe.

A structural econometric model, based on the strategic trade model and the new empirical industrial organization literature, is specified and estimated. The downward sloping demand function allows the estimation of market structures ranging from perfect competition to perfect collusion/monopoly. The empirical results show that both Florida and São Paulo FCOJ processors exert market power in the United States, but São Paulo exerts greater market power. Since São Paulo processors control 84% of the European market, they exert more market power in Europe than in the United States.

The estimated structural model is simulated to quantify the impact of a 25% reduction in both the U.S. and European tariffs. The simulation results corroborate the qualitative results of the analytical model and also provide quantitative measures of effects. The reduction in the U.S. tariff causes Florida's market share to decline and São Paulo's market share to increase in the United States. This also leads to higher U.S. and São Paulo welfare and lower European welfare. The decline in the European tariff causes São Paulo to reallocate their exports from the United States to Europe, resulting in a higher U.S. market share for Florida and a lower market share for São Paulo. This tariff reduction causes European and São Paulo welfare to rise and U.S. welfare to decline.

Our analysis shows that further reduction in the U.S. tariff, which may result from trade negotiations, will increase competition and adversely impact Florida processors, but U.S. consumer will benefit. Consequently, for Florida processors to effectively compete with São Paulo processors, it is in their best interest to continue to make progress in cost reducing technology both in

orange juice and orange production.

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Appendix A

This appendix derives the comparative statics and changes in welfare for the subsection 2.2.

Comparative Statics

The profit functions for Florida and São Paulo FCOJ processors are

$$
\begin{aligned}
\pi^f &= p^u\left(q^u\right)q^f - C^f\left(q^f\right) - F^f \\
\pi^s &= \frac{p^u\left(q^u\right)}{\left(1+\tau^u\right)}q^{su} + \frac{p^e\left(q^{se}\right)}{\left(1+\tau^e\right)}q^{se} - C^s\left(\frac{q^{su}}{g^u} + \frac{q^{se}}{g^e}\right) - F^s.
\end{aligned}
$$

The reaction functions are defined by the first-order conditions:

$$
\begin{aligned}
\pi^f_{q^f} &= \frac{\partial p^u}{\partial q^f}q^f + p^u - \frac{\partial C^f}{\partial q^f} = 0 \\
\pi^s_{q^{su}} &= \frac{1}{\left(1+\tau^u\right)}\left(\frac{\partial p^u}{\partial q^{su}}q^{su} + p^u\right) - \frac{\partial C^s}{\partial q^{su}} = 0 \\
\pi^s_{q^{se}} &= \frac{1}{\left(1+\tau^e\right)}\left(\frac{\partial p^{se}}{\partial q^{se}}q^{se} + p^e\right) - \frac{\partial C^s}{\partial q^{se}} = 0.
\end{aligned}
$$

Since the demand functions are downward sloping and the cost function is convex, we know the reaction function constitute a solution because the profit functions are globally concave implying the second-order conditions for a maximum are satisfied. Specifically, the second-order conditions are:[10]

$$
\begin{aligned}
\pi^f_{q^f q^f} &= \frac{\partial^2 p^u}{\partial q^f \partial q^f}q^f + 2\frac{\partial p^u}{\partial q^f} - \frac{\partial^2 C^f}{\partial q^f \partial q^f} < 0, \\
\pi^f_{q^f q^{su}} &= \frac{\partial^2 p^u}{\partial q^f \partial q^{su}}q^f + \frac{\partial p^u}{\partial q^{su}} < 0, \\
\pi^f_{q^f q^{se}} &= 0, \\
\pi^s_{q^{su} q^f} &= \frac{\partial^2 p^u}{\partial q^{su} \partial q^f}q^{su} + \frac{\partial p^u}{\partial q^f} < 0, \\
\pi^s_{q^{su} q^{su}} &= \frac{\partial^2 p^u}{\partial q^{su} \partial q^{su}}q^{su} + 2\frac{\partial p^u}{\partial q^{su}} - \left(1+\tau^u\right)\frac{\partial^2 C^s}{\partial q^{su} \partial q^{su}} < 0,
\end{aligned}
$$

---

[10]To derive analytical results, we assume Cournot competition.

The impact of a change in the tariff on the marginal change in profits is given by

$$\pi^f_{q^f \tau^u} = 0, \qquad \pi^f_{q^f \tau^e} = 0, \qquad \pi^s_{q^{se} \tau^u} = 0, \qquad \pi^s_{q^{su} \tau^e} = 0,$$

$$\pi^s_{q^{su} \tau^u} = -\frac{1}{(1+\tau^u)^2} \left(\frac{\partial p^u(q^u)}{\partial q^{su}} q^{su} + p^u(q^u) \right) < 0$$

$$\pi^s_{q^{se} \tau^e} = -\frac{1}{(1+\tau^e)^2} \left(\frac{\partial p^{se}(q^{se})}{\partial q^{se}} q^{se} + p^e(q^{se}) \right) < 0.$$

Totally differentiating the FOCs yields a system of three equations, written in the form $Ax = d$ we get,

$$
\begin{bmatrix}
\pi^f_{q^f q^f} & \pi^f_{q^f q^{su}} & 0 \\
\pi^s_{q^{su} q^f} & \pi^s_{q^{su} q^{su}} & \pi^s_{q^{su} q^{se}} \\
0 & \pi^s_{q^{se} q^{su}} & \pi^s_{q^{se} q^{se}}
\end{bmatrix}
\begin{bmatrix}
dq^f \\
dq^{su} \\
dq^{se}
\end{bmatrix}
= -
\begin{bmatrix}
\pi^f_{q^f \tau^u} d\tau^u + \pi^f_{q^f \tau^e} d\tau^e \\
\pi^s_{q^{su} \tau^u} d\tau^u + \pi^s_{q^{su} \tau^e} d\tau^e \\
\pi^s_{q^{se} \tau^u} d\tau^u + \pi^s_{q^{se} \tau^e} d\tau^e
\end{bmatrix}.
$$

The determinant of A is positive as shown by $|A| = \pi^f_{q^f q^f} \pi^s_{q^{su} q^{su}} \pi^s_{q^{se} q^{se}} - \pi^f_{q^f q^f} \pi^s_{q^{su} q^{se}} \pi^s_{q^{se} q^{su}} - \pi^f_{q^f q^{su}} \pi^s_{q^{su} q^f} \pi^s_{q^{se} q^{se}} > 0.$

We analyze the effect of a change in τ^u and τ^e on q^f, q^{su}, and q^{se} by applying Cramer's rule. First, consider the effect of a change in the tariffs on q^f:

$$
dq^f = \frac{1}{|A|}
\begin{vmatrix}
\pi^f_{q^f \tau^u} d\tau^u + \pi^f_{q^f \tau^e} d\tau^e & \pi^f_{q^f q^{su}} & 0 \\
\pi^s_{q^{su} \tau^u} d\tau^u + \pi^s_{q^{su} \tau^e} d\tau^e & \pi^s_{q^{su} q^{su}} & \pi^s_{q^{su} q^{se}} \\
\pi^s_{q^{se} \tau^u} d\tau^u + \pi^s_{q^{se} \tau^e} d\tau^e & \pi^s_{q^{se} q^{su}} & \pi^s_{q^{se} q^{se}}
\end{vmatrix}
$$

$$\frac{dq^f}{d\tau^u} = -\frac{1}{|A|} \pi^f_{q^f q^{su}} \pi^s_{q^{se} q^{se}} \pi^s_{q^{su} \tau^u} = -(+)(-)(-)(-) > 0$$

$$\frac{dq^f}{d\tau^e} = \frac{1}{|A|} \pi^f_{q^f q^{su}} \pi^s_{q^{su} q^{se}} \pi^s_{q^{se} \tau^e} = (+)(-)(-)(-) < 0.$$

Next, we determine the impact of a change in the tariffs on q^{su}:

$$
dq^{su} = \frac{1}{|A|}
\begin{vmatrix}
\pi^f_{q^f q^f} & \pi^f_{q^f \tau^u} d\tau^u + \pi^f_{q^f \tau^e} d\tau^e & 0 \\
\pi^s_{q^{su} q^f} & \pi^s_{q^{su} \tau^u} d\tau^u + \pi^s_{q^{su} \tau^e} d\tau^e & \pi^s_{q^{su} q^{se}} \\
0 & \pi^s_{q^{se} \tau^u} d\tau^u + \pi^s_{q^{se} \tau^e} d\tau^e & \pi^s_{q^{se} q^{se}}
\end{vmatrix}
$$

$$\frac{dq^{su}}{d\tau^u} = \frac{1}{|A|} \left(\pi^f_{q^f q^f} \pi^s_{q^{se} q^{se}} \pi^s_{q^{su} \tau^u} \right) = (+)(-)(-)(-) < 0$$

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$$\frac{dq^{su}}{d\tau^e} = -\frac{1}{|A|}\pi^f_{q^f q^f}\pi^s_{q^{su}q^{se}}\pi^s_{q^{se}\tau^e} = -(+)(-)(-)(-) > 0.$$

Next, we analyze the effect of a change in the tariffs on q^{se}:

$$dq^{se} = \frac{1}{|A|}\begin{vmatrix} \pi^f_{q^f q^f} & \pi^f_{q^f q^{su}} & \pi^f_{q^f \tau^u}d\tau^u + \pi^f_{q^f \tau^e}d\tau^e \\ \pi^s_{q^{su}q^f} & \pi^s_{q^{su}q^{su}} & \pi^s_{q^{su}\tau^u}d\tau^u + \pi^s_{q^{su}\tau^e}d\tau^e \\ 0 & \pi^s_{q^{se}q^{su}} & \pi^s_{q^{se}\tau^u}d\tau^u + \pi^s_{q^{se}\tau^e}d\tau^e \end{vmatrix}$$

$$\frac{dq^{se}}{d\tau^u} = \frac{1}{|A|}\left(-\pi^f_{q^f q^f}\pi^s_{q^{se}q^{su}}\pi^s_{q^{su}\tau^u}\right) = -(+)(-)(-)(-) > 0$$

$$\begin{aligned}
\frac{dq^{se}}{d\tau^e} &= \frac{1}{|A|}\left(-\pi^f_{q^f q^{su}}\pi^s_{q^{su}q^f}\pi^s_{q^{se}\tau^e} + \pi^f_{q^f q^f}\pi^s_{q^{su}q^{su}}\pi^s_{q^{se}\tau^e}\right) \\
&= \frac{1}{|A|}\left((-(-)(-)+(-)(-))(-)\right) < 0
\end{aligned}$$

because the own effects on marginal profits dominate the cross effects: $\pi^f_{q^f q^{su}}\pi^s_{q^{su}q^f} < \pi^f_{q^f q^f}\pi^s_{q^{su}q^{su}}$.

Finally, we analyze the effect of a change in the tariffs on q^u:

$$\begin{aligned}
\frac{dq^u}{d\tau^u} &= \frac{dq^{su}}{d\tau^u} + \frac{dq^f}{d\tau^u} \\
&= \frac{1}{|A|}\pi^s_{q^{se}q^{se}}\pi^s_{q^{su}\tau^u}\left(\pi^f_{q^f q^f} - \pi^f_{q^f q^{su}}\right) \\
&= (+)(-)(-)[(-) - (-)]
\end{aligned}$$

This result is indeterminate, but the direct effect $\left(\dfrac{dq^{su}}{d\tau^u}\right)$ will dominate the indirect effect $\left(\dfrac{dq^f}{d\tau^u}\right)$.

$$\begin{aligned}
\frac{dq^u}{d\tau^e} &= \frac{dq^{su}}{d\tau^e} + \frac{dq^f}{d\tau^e} \\
&= \frac{1}{|A|}\pi^s_{q^{su}q^{se}}\pi^s_{q^{se}\tau^e}\left(-\pi^f_{q^f q^f} + \pi^f_{q^f q^{su}}\right) \\
&= (+)(-)(-)[(+) + (-)]
\end{aligned}$$

This result is indeterminate, but the direct effect $\left(\dfrac{dq^{su}}{d\tau^e}\right)$ will dominate the indirect effect $\left(\dfrac{dq^f}{d\tau^e}\right)$.

Welfare Analysis of Tariff Changes

The welfare function for the United States is:

$$W^u \left(q^u, q^{su}; \tau^u, \tau^e \right) = \pi^f + CS + TR$$

where $\pi^f = p^u \left(q^u \right) q^f - C^f \left(q^f \right) - F^f$, $CS = \int p^u \left(q^u \right) dq^u - p^u \left(q^u \right) q^u$, and $TR = \tau^u q^{su}$. The welfare function for the São Paulo is:

$$W^s \left(q^u, q^{su}, q^{se}; \tau^u, \tau^e \right) = \pi^s$$

where $\pi^s = \dfrac{p^u \left(q^u \right)}{\left(1 + \tau^u \right)} q^{su} + \dfrac{p^e \left(q^{se} \right)}{\left(1 + \tau^e \right)} q^{se} - C^s \left(\dfrac{q^{su}}{g^u} + \dfrac{q^{se}}{g^e} \right) - F^s$. Since Europe only consumes FCOJ and collects tariff revenues, the European welfare is:

$$W^e \left(q^{se}; \tau^e, \tau^u \right) = CS + TR$$

where $CS = \int p^e \left(q^{se} \right) dq^{se} - p^e \left(q^{se} \right) q^{se}$ and $TR = p^e \left(q^{se} \right) \tau^e q^{se}$.

U.S. Tariff

The change in Florida's profit with respect to a change in the U.S. tariff is:[11]

$$\begin{aligned}
\frac{d\pi^f}{d\tau^u} &= \underbrace{\left(q^f \frac{\partial p^u}{\partial q^u} + p^u - \frac{\partial C^f}{\partial q^f} \right)}_{=0 \text{ by } FOC} \frac{\partial q^f}{\partial \tau^u} + q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u} \\
&= q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u}.
\end{aligned}$$

The change in U.S. consumer surplus with respect to a change in the U.S. tariff is:

$$\frac{dCS}{d\tau^u} = -q^u \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^u}.$$

The change in U.S. tariff revenues with respect to a change in the U.S. tariff is:

$$\frac{dTR}{d\tau^u} = \tau^u \frac{\partial q^{su}}{\partial \tau^u} + q^{su}.$$

Therefore, we can express the total change in welfare as:

---

[11]By the Cournot assumption $\dfrac{\partial q^u}{\partial q^f}$ and $\dfrac{\partial q^u}{\partial q^{su}}$ are equal to 1.

$$\frac{dW^u(\cdot)}{d\tau^u} = \underbrace{q^f \frac{\partial p^u}{\partial q^u} \frac{\partial q^{su}}{\partial \tau^u}}_{+} \underbrace{- \frac{\partial p^u}{\partial q^u} \frac{\partial q^u}{\partial \tau^u} q^u}_{-} + \underbrace{\frac{\partial q^{su}}{\partial \tau^u} \tau^u}_{-} + \underbrace{q^{su}}_{+}.$$

The above results show that the welfare could be positive or negative.

The change in São Paulo welfare arising from a change in U.S. and European tariff is

$$\begin{aligned}
\frac{dW^s(\cdot)}{d\tau^u} &= \underbrace{\left(\frac{1}{(1+\tau^u)} \left(q^{su} \frac{\partial p^u}{\partial q^u} + p^u \right) - \frac{\partial C^s}{\partial q^{su}} \right) \frac{\partial q^{su}}{\partial \tau^u}}_{=0 \text{ by } FOC} \\
&\quad + \underbrace{\left(\frac{1}{(1+\tau^e)} \left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) - \frac{\partial C^s}{\partial q^{se}} \right) \frac{\partial q^{se}}{\partial \tau^u}}_{=0 \text{ by } FOC} \\
&\quad + \frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^u} - \frac{p^u q^{su}}{(1+\tau^u)^2} \\
&= \underbrace{\frac{1}{(1+\tau^u)} q^{su} \frac{\partial p^u}{\partial q^u} \frac{\partial q^f}{\partial \tau^u}}_{-} \underbrace{- \frac{p^u q^{su}}{(1+\tau^u)^2}}_{-} < 0.
\end{aligned}$$

Thus, São Paulo's welfare increase as the U.S. reduces its tariff.

The change in European consumer surplus arising from a change in U.S. tariff is

$$\frac{dCS}{d\tau^u} = -q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u}.$$

The change in European tariff revenue arising from a change in U.S. tariff is

$$\frac{dTR}{d\tau^u} = \tau^e q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u} + p^e(q^{se}) \tau^e \frac{\partial q^{se}}{\partial \tau^u}.$$

The total change in the European welfare is expressed as:

$$\frac{dW^e(\cdot)}{d\tau^u} = \underbrace{-q^{se} \frac{\partial p^e}{\partial q^{se}} \frac{\partial q^{se}}{\partial \tau^u}}_{+} + \underbrace{\left(q^{se} \frac{\partial p^e}{\partial q^{se}} + p^e \right) \tau^e \frac{\partial q^{se}}{\partial \tau^u}}_{+} > 0.$$

Thus, the above result shows that European welfare decreases as the United States reduces its tariff.

European Tariff

The change in Florida's profits with respect to a change in τ^e is:

$$
\begin{aligned}
\frac{d\pi^f}{d\tau^e} &= \underbrace{\left(q^f\frac{\partial p^u}{\partial q^u} + p^u - \frac{\partial C^f}{\partial q^f}\right)\frac{\partial q^f}{\partial \tau^e}}_{=0 \text{ by } FOC} + q^f\frac{\partial p^u}{\partial q^u}\frac{\partial q^{su}}{\partial \tau^e} \\
&= q^f\frac{\partial p^u}{\partial q^u}\frac{\partial q^{su}}{\partial \tau^e}.
\end{aligned}
$$

The change in the U.S. consumer surplus with respect to a change in τ^e is:

$$
\frac{dCS}{d\tau^e} = -q^u\frac{\partial p^u}{\partial q^u}\frac{\partial q^u}{\partial \tau^e}.
$$

The change in the U.S. tariff revenue with respect to a change in τ^e is:

$$
\frac{dTR}{d\tau^e} = \tau^u\frac{\partial q^{su}}{\partial \tau^e}.
$$

Thus the total change in U.S. welfare with respect to τ^e is:

$$
\frac{dW^u(\cdot)}{d\tau^e} = \underbrace{q^f\frac{\partial p^u}{\partial q^u}\frac{\partial q^{su}}{\partial \tau^e}}_{-} \underbrace{-q^u\frac{\partial p^u}{\partial q^u}\frac{\partial q^u}{\partial \tau^e}}_{+} + \underbrace{\tau^u\frac{\partial q^{su}}{\partial \tau^e}}_{+}.
$$

The above results show that the U.S. welfare can increase or decrease as Europe reduces the tariff.

The change in São Paulo welfare arising from a change in the European tariff is

$$
\begin{aligned}
\frac{dW^s}{d\tau^e} &= \underbrace{\left(\frac{1}{(1+\tau^u)}\left(q^{su}\frac{\partial p^u}{\partial q^u} + p^u\right) - \frac{\partial C^s}{\partial q^{su}}\right)\frac{\partial q^{su}}{\partial \tau^e}}_{=0 \text{ by } FOC} \\
&\quad + \underbrace{\left(\frac{1}{(1+\tau^e)}\left(q^{se}\frac{\partial p^e}{\partial q^{se}} + p^e\right) - \frac{\partial C^s}{\partial q^{se}}\right)\frac{\partial q^{se}}{\partial \tau^e}}_{=0 \text{ by } FOC} \\
&\quad + \frac{1}{(1+\tau^u)}q^{su}\frac{\partial p^u}{\partial q^u}\frac{\partial q^f}{\partial \tau^e} - \frac{p^e q^{se}}{(1+\tau^e)^2} \\
&= \underbrace{\frac{1}{(1+\tau^u)}q^{su}\frac{\partial p^u}{\partial q^u}\frac{\partial q^f}{\partial \tau^e}}_{+} \underbrace{- \frac{p^e q^{se}}{(1+\tau^e)^2}}_{-}
\end{aligned}
$$

The São Paulo Welfare can go up or fall (most likely go up) when Europe reduces its tariff. São Paulo is going to gain from the European market as it can sell more, leading to a positive gain, but will lose in the United States as it switches exports from the United States to Europe and lose

market share to Florida.

The change in the European consumer surplus arising from a change in the European tariff is:

$$\frac{dCS}{d\tau^e} = -q^{se}\frac{\partial p^e}{\partial q^{se}}\frac{\partial q^{se}}{\partial \tau^u}.$$

The change in the European tariff revenues arising from a change in the European tariff is:

$$\frac{dTR}{d\tau^e} = \tau^e q^{se}\frac{\partial p^e}{\partial q^{se}}\frac{\partial q^{se}}{\partial \tau^e} + p^e\tau^e\frac{\partial q^{se}}{\partial \tau^e} + p^e q^{se}.$$

The total change in welfare is:

$$\frac{dW^e\left(\cdot\right)}{d\tau^e} = \underbrace{-q^{se}\frac{\partial p^e}{\partial q^{se}}\frac{\partial q^{se}}{\partial \tau^e}}_{-} + \underbrace{\left(q^{se}\frac{\partial p^e}{\partial q^{se}} + p^e\right)\tau^e\frac{\partial q^{se}}{\partial \tau^e}}_{-} + \underbrace{p^e q^{se}}_{+}.$$

As Europe reduces its tariff its consumer surplus will increase but tariff revenues will go down, but the net results will likely be positive as the gain in consumer surplus will most likely outweigh the loss in tariff revenues.