

Production and Price Effects of New Diseases and Other Challenges Confronting the Processed Orange Industry

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Introduction

The world orange juice industry is dominated by two supply regions: Sao Paulo, Brazil and Florida, United States. These two regions collectively account for approximately 80 percent of world orange juice production. Presently, both regions are facing production challenges. In Sao Paulo, these threats include several diseases and competition from sugarcane production. The recent increase in world oil prices has stimulated widespread interest in expansion of sugarcane production in Brazil as a feedstock for ethanol production. Acreage allocated to sugarcane production has grown to the point that most of the citrus production in northern Sao Paulo state has ceased.

In Florida, new diseases, namely citrus canker and citrus greening (aka Huanglongbing) pose threats to economic viability of citrus production. Florida citrus growers are also facing increasing factor costs as population growth has significantly increased the price of rural land. The threat of major immigration reform may also have ramifications for the cost of labor, most of which is supplied by immigrants from Mexico and other Latin American countries.

The purpose of this paper is to develop a model of the world orange juice market capable of quantifying the impacts of these supply challenges on future orange juice production and

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consumption. The model used for this analysis is a spatial equilibrium model with implicit supply as originally proposed by Takayama and Judge and later discussed by McCarl and Spreen. As the basic model used here has been previously reported in Spreen, Brewster and Brown, the discussion will not provide a detailed derivation of the model. Rather an overview of the model is provided combined with a discussion of how the model is modified to account for the effect of the factors outlined elsewhere on orange production in Sao Paulo and Florida. Given page length limitations, the discussion in this paper focuses on the impact of citrus greening which is currently present in both Sao Paulo and Florida and the effect of high sugarcane prices in Brazil.

Overview of the World Orange Juice Market

Even though in terms of volume, orange juice is the most important fruit juice produced in the world, and its production is confined primarily to two production regions: Sao Paulo, Brazil and Florida, United States. Over the past two decades, Sao Paulo and Florida have produced 80 to 85 percent of total orange juice production. With the exception of Belize, Costa Rica, and Cuba, all other important orange producing countries send most of their production to the fresh market, with processed utilization limited to that fruit that does not make fresh market standards. Following Sao Paulo and Florida, other suppliers of orange juice include Mexico, Costa Rica, Belize, Cuba, Australia, Spain, California, Italy, Argentina, and China. None of these other regions have a world supply share exceeding two percent.

Orange juice consumption occurs primarily in the developed economies of North American and Western Europe. The United States and the European Union each consume approximately 1.3 billion single strength equivalent (SSE) gallons of orange juice annually. The

third largest market is Canada with annual consumption of approximately 160 million SSE gallons, and Japan ranks fourth with 125 million SSE gallons. Other consuming regions include Russia, China, South Korea, and Australia. Total world consumption is approximately 3.5 billion SSE gallons.

Orange juice is purchased in three forms: frozen concentrated orange juice (FCOJ), reconstituted from FCOJ single strength (also known as recon), and not-from-concentrate or NFC. This distinction is important for several reasons. First, nearly all orange juice production in Sao Paulo is FCOJ. Since the domestic market in Brazil is negligible, virtually all of its production is exported. Transportation costs associated with FCOJ are far lower compared to single-strength orange juice. The Brazilians have developed a technology that allows bulk shipment in tanker ships of FCOJ similar to that used for crude oil. In Florida, approximately one-half of its orange juice production is NFC which is sold in the United States and Canada. Brands such as Tropicana have been successful in conveying the message that NFC has a superior taste compared to from concentrate orange juice so that NFC has gained major market share in the United States and to a lesser extent in Canada. NFC commands a significant price premium over FCOJ and reconstituted OJ in the retail market.

A Model of the World Orange Juice Market

A model of the world orange juice market has been developed cooperatively between the University of Florida and the Florida Department of Citrus. Earlier versions of the model are reported in McClain and Spreen, Brewster, and Brown. A schematic of the model is presented in Figures 1 and 2. The model includes two endogenous supply regions: Sao Paulo and Florida. It also includes four endogenous demand regions: the United States, the European Union, Canada,

and Japan which serves as a proxy for the rest of the world. OJ consumption in the United States and Canada is differentiated between NFC and FCOJ given the importance of NFC in both markets.

Explicit supply equations are not estimated for Sao Paulo and Florida. Rather the link between supply and price is through a new planting equation. Higher prices stimulate new plantings. New plantings take three years to begin to bear fruit and 8-12 years to reach full production. High quality information is available on the number of orange trees in Florida by variety and age. Although some data on tree numbers in Sao Paulo is available, the tree-age distribution must be inferred through new plantings data and informal sources regarding tree mortality. There is an asymmetry in supply response as low prices do not necessarily lead to tree removal. Disease and weather events, however, serve to continually cause attrition in the tree population. Kalaitzandonakes and Shonkwiler model the distinction between replacement planting and new grove investment planting.

Let n_{ia} be the number of trees in age category a in region i where i can equal Florida or Sao Paulo, and let Y_{ia} be the yield of oranges per tree associated with a tree of age a located in production region i . Then:

$$(1) \quad \sum_a n_{ia} Y_{ia} = TP_i$$

is the total production of oranges in region i .

In Florida, processed orange utilization is high and has remained relatively constant at 95% over recent years. In Sao Paulo, a larger proportion of orange production is utilized in its internal market as fresh oranges (which often are juiced at home). Processed utilization in Sao

Paulo ranges from 80-85% of total orange production. In this model, assume that processed orange utilization is a fixed proportion of the crop and is given by U_i .

$$(2) \quad OJ_i = TP_i * U_i * JU_i$$

where OJ_i is orange juice production in region i , and JU_i is a conversion factor between fresh oranges and the volume of orange juice.

The presence of two products in Florida, NFC and FCOJ, however, complicates the conversion of fresh oranges to orange juice. A separate sub-model must be developed in order to model the allocation of oranges to NFC and FCOJ. For more detail on this portion of the model see Spreen, et al. (2003).

In the current specification of the model, the demand for FCOJ and NFC vary across the four consumption regions: the United States, Canada, the European Union (EU), and Japan. In the European Union, and Japan the main processed orange product consumed is frozen concentrated orange juice (FCOJ). In the United States and Canada, however, not-from-concentrate (NFC) now accounts for approximately 45% and 30% of orange juice consumption, respectively.

To account for the presence of NFC, a two-equation inverse demand system is estimated for the United States and Canada. The linear form of this system is:

$$(3) \quad P_{FCOJ} = \alpha_1 - \beta_1 Q_{FCOJ} + \gamma_1 Q_{NFC} .$$

$$(4) \quad P_{NFC} = \alpha_2 - \beta_2 Q_{NFC} + \gamma_2 Q_{FCOJ}$$

where P_{FCOJ} is the processor price of FCOJ, P_{NFC} is the processor price of NFC, Q_{FCOJ} is the quantity of FCOJ⁶, and Q_{NFC} is the quantity of NFC consumed.

The parameters γ_1 and γ_2 are the “cross-price” effects; i.e., the impact of a change in the quantity of one product on the price of another product. In order to formulate the quadratic programming model which will determine the optimal allocation of orange juice across product forms and spatially separated markets, it must be assumed that $\gamma_1 = \gamma_2$. For further discussion see McCarl and Spreen. The demand system denoted by equations (3) and (4) is estimated individually for the United States and Canada.

For the other consumption regions, let the inverse demand equation be given by

$$(5) \quad P_j = a_j - b_j Q_j$$

where P_j is the price of FCOJ in region j ($j =$ European Union or Japan), and Q_j is the quantity of FCOJ consumed in region j .

To complete the model, two more issues must be considered. First consider the tariffs imposed on imported orange juice. The United States applies a per unit tariff on imports from Brazil. In the framework of a spatial equilibrium model, per unit tariffs are added to transportation costs so that the transfer cost from region i to region j is $T_{ij} = t_{ij} + tar_j$ where t_{ij} is the per unit transportation cost and tar_j is the tariff imposed by region j . The European Union and Japan, however, use ad valorem tariffs. Ad valorem tariffs are percentage tariffs. In a standard spatial equilibrium model, integrating the demand function and summing across regions forms the objective function. To simplify the exposition, if all demand equations are of the form $P_j = a_j - b_j Q_j$, and there are J demand regions, then the objective function looks like

$$\sum_{j=1}^J \int_0^{Q_j} (a_j - b_j Q_j) dQ_j \quad \text{or} \quad \sum_{j=1}^J (a_j Q_j - \frac{1}{2} b_j Q_j^2)$$

The ad valorem tariff is imposed by dividing the integral by one plus the tariff (AD) expressed as a decimal, or

$$(6) \quad \sum_{j=1}^J \frac{1}{1+AD_j} (a_j Q_j - \frac{1}{2} b_j Q_j^2)$$

The other issue relates to new plantings. Based upon previous work of McClain, and Kalaitzandonakes and Shonkwiler, new plantings react to current and lagged on-tree prices; i.e., $NP_{t+1} = f(ON_t, ON_{t-1}, \dots, ON_{t-k})$ where NP_t is new plantings in year t , ON_t is the on-tree (or grower) price in year t , k is the number of years in the lag structure.

In the present study, separate planting relationships for early and midseason oranges and Valencia oranges grown in Florida are estimated. Planting levels are related to expected on-tree price variables for oranges. Data on planting levels and on-tree prices were obtained from publications by the Florida Agricultural Statistics Service. Annual data from 1965 through 2006 (42 observations) were studied.

An autoregressive model was estimated of the form

$$(7) \quad NP_{t+1} = NP_t + a(ON_t - ON_{t-1})$$

and incorporated into the model.

In Sao Paulo, citrus must compete with sugarcane for land and capital. The new planting equation for Sao Paulo takes the form

$$(8) \quad NP_{t+1} = NP_t + b(ON_t/SC_t - ON_{t-1}/SC_{t-1})$$

where SC_t is the price paid for sugarcane in Sao Paulo in period t .

To write the complete model, note that it has two main components: the production sub-models for Sao Paulo and Florida and the pricing model. The production model for year t uses the price equilibrium from year $t - 1$ to compute on-tree prices in Sao Paulo and Florida. These prices are used in equations (7) and (8) to predict new plantings in each region. Trees of age $a - 1$ in year $t - 1$ are moved to age a in year t , adjusted for death loss; i.e.

$$(9) \quad n_{i,a,t} = n_{i,a-1,t-1} * (1 - DL_{i,a-1})$$

where $DL_{i,a-1}$ is the death loss associated with trees of age $a - 1$ in region i . Once the new tree age distribution is known, equations (1) and (2) are used to project orange juice production in both regions. After $OJ_{iv,t}$ is calculated, it is used as input into the spatial equilibrium model.

Omitting the time subscript for simplicity, the spatial model is

$$(10) \max \sum_{j=EU, Japan} \frac{1}{1 + AD_j} \left(a_j Q_j - \frac{1}{2} b_j Q_j^2 \right) +$$

$$\sum_{j=US, Canada} \left[\int (\alpha_{1j} - \beta_{1j} Q_{j,FCOJ} + \gamma_{1j} Q_{j,NFC}) dQ_{j,FCOJ} \right. \\ \left. + \int (\alpha_{2j} - \beta_{2j} Q_{j,NFC} + \gamma_{2j} Q_{j,FCOJ}) dQ_{j,NFC} \right]$$

$$- \sum_i \sum_j \sum_p T_{ijp} X_{ijp}$$

$$s.t. \quad - \sum_i X_{ijp} + Q_{jp} \leq 0$$

$$- Y_{ip} + \sum_j X_{ijp} \leq 0$$

$$- \sum_v Z_{ivp} + Y_{ip} \leq 0$$

$$\sum_p JU_{iv} Z_{ivp} \leq OJ_{iv}$$

$$\sum_v a_{ivpc} Z_{ivp} \leq QU_{ipc}$$

$$\sum_v a_{ivpc} Z_{ivp} \geq QL_{ipc}$$

and all variables are non-negative where X_{ijp} , Q_{jp} , OJ_{iv} , and Z_{ivp} are defined as before. Y_{ip} is the quantity of product p produced in supply region i , and JU_{iv} is the juice yield per box associated with variety v produced in region i .

Model Validation

The mathematical programming problem (10) was solved using the GAMS software. The model was validated using the 2006-07 season as the base year. The model performed reasonably well in predicting the on-tree (grower) price in Florida as reported by the Florida Agricultural Statistics Service (FASS) and also producing the appropriate proportion of FCOJ and NFC for both the U.S. and Canadian market. As the on-tree price for Sao Paulo is not published, it is not possible to fully validate the Brazilian portion of the model, although the predicted FOB FCOJ price for Sao Paulo corresponded to the quoted price in Rotterdam for Brazilian FCOJ.

Modification of the Model

In this paper, two supply related scenarios are considered. The first scenario relates to the impact of citrus greening on production in both Sao Paulo and Florida. The second scenario considers the impact of high sugarcane prices in Sao Paulo and the competition between sugarcane and citrus for land in Sao Paulo.

To account for the presence of greening in both Sao Paulo and Florida, tree mortality rates have been modified in the base model. For more detail about greening and its effects on citrus trees see Spreen et al. While the precise impact of greening in both production regions is not known, the approach taken in the paper is to increase tree mortality by 50 percent for

younger trees and by 25 percent for older trees. As the insect (the Asiatic psyllid) which serves as the vector for the disease attacks new growth on the trees, it is assumed that younger trees, which are more vigorous will be more susceptible to the disease compared to older trees. In terms of equation (9), this means the parameter $DL_{i, a-1}$ is modified for both Sao Paulo and Florida.

The second scenario relates to the effect of high sugarcane prices on new citrus tree plantings in Sao Paulo. In equation (8), note that the price of sugarcane is included as a parameter in the new plantings equation for Sao Paulo. In the baseline version of the model, a value of $SC = 191$ is used to represent the price of sugarcane. This is the recent price in Brazilian currency being paid for sugarcane delivered to the mill. In the lower cane price scenario, this price is reduced by 50 percent, a price comparable to that observed before the recent run-up in world oil prices.

Empirical Results

Projected orange production in Florida under the three alternative scenarios is shown in Table 1. The base results include the presence of greening in both Sao Paulo and Florida. In the no greening scenario, tree mortality rates are decreased to historical levels in both Florida and Sao Paulo, i.e. the impact of greening is eliminated. With the tree mortality assumptions used in this paper, the impact of citrus greening on Florida is estimated to reduce future orange production by five to 28 million boxes beginning in 2011-12 season with the gap widening over the forecast horizon. In the 2026-27 season, the projected production impact is approximately 18 percent of the baseline production.

In Table 2, projected orange production in Sao Paulo under the three alternative scenarios is shown. The absolute impact of greening on orange production in Sao Paulo is projected to be larger compared to Florida with production impacts of nearly 80 million boxes per year. When calculated on a percentage basis, however, projected production decreases are less than 20 percent.

In Table 3, projected U.S. FOB FCOJ prices are shown under the three alternative scenarios considered. The FOB FOCJ price is still used as the benchmark price in the orange juice market as this corresponds to the price in the New York Board of Trade futures contract. The impact of greening on OJ prices is projected to be approximately \$.25 per pound solid over most of the forecast horizon. This price impact is approximately equal to \$.25 per SSE gallon which is a sizeable impact at the wholesale level. If this price change were transmitted through the marketing system, this would translate to an approximate six percent rise in retail reconstituted OJ prices.

The impact of lower sugarcane prices on Florida and Sao Paulo orange production is also shown in Tables 1 and 2, respectively. Lower sugarcane prices means less competition from cane for agricultural land in Sao Paulo resulting in larger plantings of orange trees. Consequently, Sao Paulo orange production rises (Table 2) which in turn depresses orange juice prices (Table 3). Lower prices negatively impact production in Florida (Table 1). While the production impact in Florida is not large, projected production in Florida trends downward throughout the forecast horizon with Florida expected to produce 140 million boxes of oranges in the 2026-27 season. The projected effect of lower cane prices on Sao Paulo orange production is

substantial with production projected at 537 million boxes in 2026-27 compared to 472 million boxes in the baseline.

The combination of higher production in Sao Paulo and lower production in Florida means that although projected prices are lower with lower sugarcane prices compared to the baseline, the price decrease is smaller compared to the no greening scenario. Lower sugarcane prices are projected to translate to lower FCOJ prices beginning in the 2011-12 season and beyond. The largest price change would occur in 2019-20 when FCOJ prices are expected to be \$.26 per pound solid lower compared to the baseline.

Concluding Remarks

Sao Paulo, Brazil and Florida are the two largest suppliers of orange juice to the world market. Both regions face an array of production issues including new diseases and rising factor costs. In this paper, two specific issues are analyzed: (1) the impact of citrus greening, a potentially devastating disease that has been recently discovered in both Sao Paulo and Florida, and (2) the effect of high sugarcane prices in Sao Paulo resulting from increased production of ethanol from sugarcane as Brazil adjusts to higher oil prices.

A model of the world orange market was used to isolate the effect of these two factors on orange production in the two regions and estimate resulting price changes. As citrus greening is already present in Florida and Sao Paulo, the baseline model included higher tree mortality rates that are expected with spread of citrus greening. The no greening scenario suggests that greening will reduce orange production in both Florida and Sao Paulo by 15 to 20 percent resulting in

wholesale FCOJ price increases of approximately 15 percent. Smaller percentage price increases would be realized at retail because of the marketing margin.

A 50 percent reduction in the Sao Paulo sugarcane price would result in expanded orange production in Sao Paulo. The concomitant price decrease, however, would cause production in Florida to contract modestly. Consumers would pay lower prices for orange juice although the estimated price impacts are not large.

Further study is needed to understand the possible impact of other production challenges facing both Sao Paulo and Florida. These challenges include other diseases in Sao Paulo such as citrus variegated chloris (CVC), sudden death, and citrus canker. In Florida, growers are also dealing with citrus canker, high rural land values, and the possibility of immigrant labor reform which could limit the supply of harvest labor.

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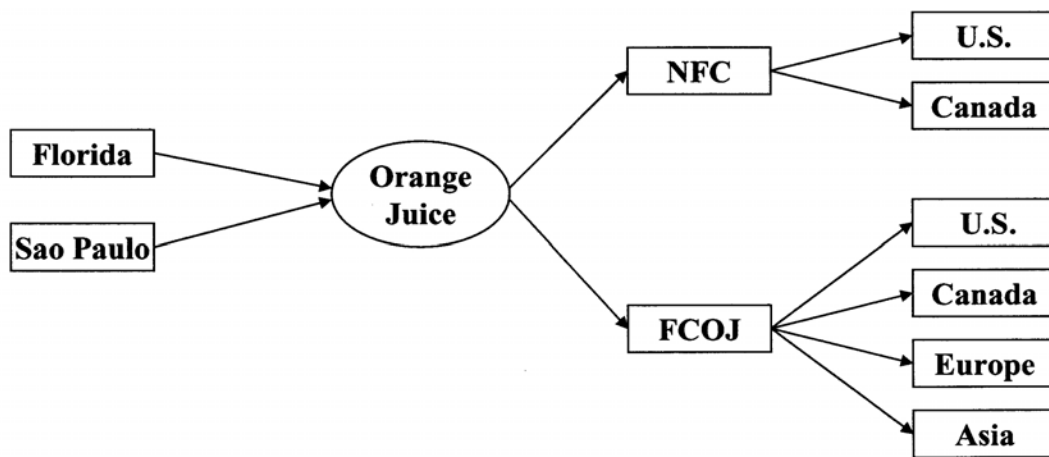


Figure 1. Production and consumption regions in world orange juice model.

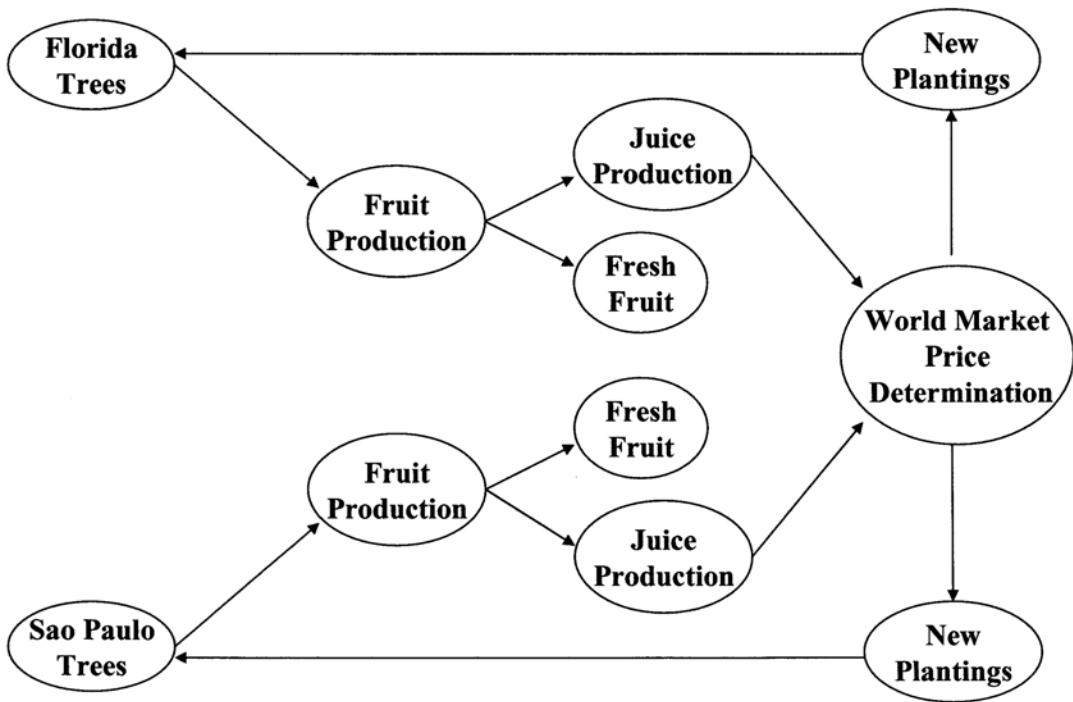


Figure 2. Flow chart of world orange juice model.

Table 1. Projected Florida orange production under alternative production scenarios, 2007-08 through 2026-27 seasons.

Season	Baseline	No Greening ----- million boxes -----	Lower Cane Prices
2007-08	168	168	168
2008-09	157	158	157
2009-10	155	156	155
2010-11	156	158	156
2011-12	153	158	153
2012-13	153	161	153
2013-14	151	163	151
2014-15	152	167	152
2015-16	152	170	152
2016-17	153	174	153
2017-18	148	170	147
2018-19	147	171	146
2019-20	148	174	146
2020-21	148	176	146
2021-22	149	177	145
2022-23	150	179	144
2023-24	151	179	143
2024-25	151	180	142
2025-26	152	180	141
2026-27	152	180	140

Table 2. Projected orange production in Sao Paulo under alternative production scenarios, 2007-08 through 2026-27 seasons.

Season	Baseline	No Greening	Lower Cane Prices
		----- million boxes -----	
2007-08	360	360	360
2008-09	357	363	357
2009-10	359	369	359
2010-11	365	379	369
2011-12	367	389	378
2012-13	370	400	388
2013-14	375	414	402
2014-15	381	428	417
2015-16	388	444	435
2016-17	396	460	453
2017-18	404	474	471
2018-19	413	488	489
2019-20	422	501	505
2020-21	430	511	517
2021-22	438	519	527
2022-23	452	530	539
2023-24	458	532	541
2024-25	464	533	541
2025-26	468	532	539
2026-27	472	531	537

Table 3. Projected US FOB FCOJ prices under alternative production scenarios, 2007-08 through 2026-27 seasons.

Season	Baseline	No Greening	Lower Cane Price
	----	\$US/pound solid	----
2007-08	1.67	1.67	1.67
2008-09	1.77	1.75	1.77
2009-10	1.80	1.76	1.80
2010-11	1.80	1.75	1.78
2011-12	1.83	1.74	1.79
2012-13	1.84	1.71	1.78
2013-14	1.86	1.69	1.77
2014-15	1.86	1.65	1.74
2015-16	1.87	1.62	1.71
2016-17	1.86	1.58	1.67
2017-18	1.88	1.57	1.66
2018-19	1.88	1.55	1.63
2019-20	1.87	1.53	1.61
2020-21	1.87	1.52	1.61
2021-22	1.87	1.52	1.61
2022-23	1.88	1.55	1.64
2023-24	1.89	1.58	1.67
2024-25	1.90	1.61	1.71
2025-26	1.91	1.65	1.75
2026-27	1.92	1.69	1.80