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The Projected Impact of Citrus Greening in Sao Paulo and Florida on Processed Orange Production and Price

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After the near record crop of the 2003–04 season, the citrus industries of Sao Paulo, Brazil, and Florida have witnessed a number of events that have powerful implications for citrus production in both regions. These events include the hurricanes of 2004 and 2005 that destroyed and damaged millions of citrus trees in Florida. In Sao Paulo, Brazil, the world's largest citrus producing area, a number of factors have been combined to limit citrus production, primarily sweet orange production intended for the processing sector. A key factor likely to affect citrus production in both regions is the presence of citrus greening. In this paper, the likely impact of citrus greening on orange production in Florida and Sao Paulo is considered along with price projections for processed oranges.

In 2002, citrus greening (also known as huanglongbing or HLB), which had previously been confined to Asia and Africa, was found in Sao Paulo, Brazil. In Aug. 2005, citrus greening was detected near Homestead, FL. Soon thereafter, it spread into isolated commercial citrus production areas in southern Florida.

Given the destructive nature of citrus greening, it poses particular challenges to citrus growers in Sao Paulo and Florida. As these two regions are the dominant suppliers of orange juice to the world market, it is likely that the disease will have implications on orange production in those two regions and ultimately on orange juice prices. The purpose of this paper is to incorporate the possible effects of citrus greening and other factors into a model of the world orange juice market developed collectively by the Florida Department of Citrus and the University of Florida.

The Model

The world orange juice market is comprised of two major suppliers: Sao Paulo and Florida, who collectively account for over 80% of world orange juice production (FAO, 2006; Citrus Summary, 2005–06). Other orange juice producing regions include Mexico, California, Costa Rica, Belize, Cuba, Argentina, Spain, and Italy. None of these other regions, however, have market shares exceeding 5%. Therefore, only supply from Sao Paulo and Florida is explicitly modeled.

Since oranges are a perennial crop, supply must be modeled in a dynamic fashion. This is accomplished by first specifying a relationship that predicts planting of new trees based upon lagged grower prices (on-tree price). Once trees are planted, they reach bearing age after 3 years of life and generally reach full production by 10 to 12 years of age. Therefore, it is necessary to track tree numbers by age until trees reach full production. There is some year-to-year tree attrition with tree death losses being lower at younger ages and higher in older trees. Even though citrus greening does not immediately kill citrus trees, it renders the tree economically unviable soon after infection. Furthermore, infected trees serve as a source of infection for other trees; therefore, most growers will immediately remove an infected tree, which is equivalent to increased death loss.

The major markets for orange juice are the United States, the European Union, Canada, and Japan. Orange juice is also consumed in other areas of the world, including Asia, Russia, and Australia, but consumption in these other countries is still a relatively small proportion of total world consumption. The evolution of the consumption of not-from-concentrate (NFC) orange juice in the United States is an important recent phenomenon; however, demand studies suggest a high degree of substitutability between NFC and from-concentrate orange juice (also known as reconstituted orange juice or simply recon) (Spreen et al., 2003); and, therefore, in the model used herein NFC and frozen concentrated orange juice (FCOJ) were aggregated into an overall orange juice category. Most orange juice consumption in the European Union and the rest of the world is from concentrate. Orange juice demand equations were estimated for the United States, the European Union, Canada, and the rest of the world, which include the price of FCOJ and a growth trend.

The supply and demand components of the model are merged by first calculating the production of orange juice in the current season. This is accomplished by taking the estimated tree inventory in Florida and multiplying the number of acres in a particular age cohort by expected average yield. After fruit production is estimated, this is converted to orange juice production by multiplying average pound solids per box times the number of boxes times the average processed utilization rate. A similar calculation is made for Sao Paulo, yielding total orange juice supply for that region. Next a spatial price equilibrium (Takayama and Judge, 1971) is established by allocating orange juice supply from Florida and Sao Paulo across consumption areas, accounting

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for transportation costs and tariffs. Once the price at each of the four consuming markets is determined, transportation costs and tariffs are subtracted to determine FOB prices in Florida and Sao Paulo. Deducting the estimated processing, harvest, and haul costs gives a grower-level or on-tree price. These on-tree prices are used to predict plantings in the next season. The model moves in a forward recursive fashion to generate production and price forecasts over several years.

Model Modifications

In this paper, the focus is on the possible impact of citrus greening on future orange production in Sao Paulo and Florida. The primary impact of greening will be to increase tree mortality. Infected trees provide a source of inoculum to be spread to other trees, so it is assumed that under best management, infected trees will be removed immediately. In this analysis, three scenarios are considered: no greening (base), low impact from greening, and high impact from greening. The assumed effects on tree mortality under these three scenarios are shown in Table 1. As noted in Table 1, the baseline level of tree mortality derived using historical data from the Commercial Citrus Tree Inventory (Florida Agricultural Statistics Service, various years) is 1% for non-bearing trees, 1.5% for trees ages 4 through 11 years, and 3.5% for trees 12 years and older. In the "low greening" scenario, these figures are increased to 2% for non-bearing trees, 2.63% for trees ages 4 through 11 years, and 5.25% for trees 12 years and older. A larger relative increase is used for younger trees based upon the argument that as young trees are more likely to flush, they will be more susceptible to attack from psyllids and, therefore, be more likely to contract greening. In the "high greening" scenario, tree mortality for non-bearing trees is increased 300% to 4%, by 200% to 4.5% for trees ages 4 through 11 years, and by 150% to 8.75% for trees 12 years and older.

Table 1. Tree loss percentages for orange trees in Florida.

Tree age (years)	Greening: Base[z]	Low	High
	%		
1–3	1.00	2.00	4.00
4–11	1.50	2.63	4.50
12+	3.50	5.25	8.75

[z]Estimated average state historical tree loss (excluding effects of development and eradication).

In Sao Paulo, similar impacts for greening are incorporated. The base level of tree mortality in Sao Paulo is higher compared to Florida because of the prevalence of blight (also known as decline). An estimate of 5% annually for all trees[1] is used as the base level of tree mortality. Under a "low greening" scenario, this figure is increased to 7.5%. Under a "high greening" scenario, tree mortality is assumed to be 9% across all tree age categories.

Long-run projections of Florida and Sao Paulo orange production along with FOB FCOJ and on-tree prices under the baseline assumptions are shown in Table 2. Also shown is projected Florida bearing tree acreage and U.S. and "rest of the world" (ROW) orange juice consumption. Under the baseline assumptions, Florida orange production is expected to decrease from 194 million boxes in the 2007–08 season to 175 million boxes by 2014–15 and then recover to 181 million boxes by 2020–21. Over the forecast horizon, the projected production decline is due to limited availability of nursery trees over the 2005–08 period resulting from canker infestation of nearly two-thirds of the citrus tree nurseries in Florida.

[1]This figure is probably too high for non-bearing trees. Data are not available, however, to allow separate estimation of tree mortality by age group. Baseline tree mortality in Sao Paulo is higher compared to Florida because of the prevalence of blight and CVC in Sao Paulo.

Table 2. Long-run projections of Florida and São Paulo orange production, U.S., and "rest of the world" (ROW) orange juice (OJ) consumption and U.S. OJ prices, base assumptions.[z]

Season	Orange: Florida production (million boxes)	Total acreage (1000 acres)	Acre-loss rate (%)	São Paulo production (million boxes)	Price: Florida bulk FCOJ ($/SSE gal)	Price: Processed on-tree ($/box)	OJ consumption: U.S. (million SSE gal)	OJ consumption: ROW (million SSE gal)
2007–08	194	504	–3.5	360	1.18	3.95	1408	2217
2008–09	191	498	–3.4	365	1.20	4.08	1412	2237
2009–10	187	504	–3.4	371	1.23	4.26	1414	2249
2010–11	183	509	–3.4	377	1.26	4.41	1418	2267
2011–12	179	515	–3.4	384	1.28	4.57	1422	2286
2012–13	178	521	–3.3	392	1.30	4.66	1430	2315
2013–14	176	527	–3.3	401	1.31	4.73	1440	2349
2014–15	175	534	–3.3	409	1.31	4.77	1452	2389
2015–16	175	541	–3.2	419	1.32	4.80	1464	2432
2016–17	175	548	–3.2	428	1.32	4.81	1479	2480
2017–18	176	555	–3.1	438	1.32	4.80	1494	2531
2018–19	177	562	–3.1	448	1.31	4.77	1511	2586
2019–20	179	569	–3.1	458	1.31	4.74	1528	2643
2020–21	181	576	–3.0	468	1.30	4.71	1545	2702

[z]Assumes 1) presence of canker will increase acre-loss rates by 10% and decrease acre yields of Valencia oranges and other citrus varieties by 5% and 10%, respectively; 2) acre yields are weighted averages of historical yields: 90% times non-hurricane yields (averages from 1993–94 through 2003–04) plus 10% times hurricane yields (2004–05); 3) U.S. and ROW OJ demands grow by 1% and 2% annually, respectively; and 4) ROW OJ supplies grow by 1% annually; FCOJ = frozen concentrated orange juice; SSE = single-strength equivalent.

While orange production in Florida is projected to decline over the next decade, under the baseline assumptions, orange production in Sao Paulo is projected to increase from 360 million boxes in the 2007–08 season to 468 million boxes in 2020–21. This increase in Sao Paulo production offsets the production decrease in Florida. Combined with growing world demand, prices are projected to increase modestly over the forecast horizon from $1.18 per single-strength equivalent (SSE) gallon in 2007–08 to a high of $1.32 per SSE gallon in 2015–16. Larger crops in Sao Paulo also support increasing consumption with U.S. OJ consumption reaching 1.545 billion SSE gallons in 2020–21 up from 1.408 billion SSE gallons in 2007–08 and ROW OJ consumption increasing from 2.217 billion gallons in 2007–08 to 2.702 billion gallons in 2020–21.

In Table 3, long-run projections of production and prices for orange juice are shown under the "low greening" scenario. Under these assumptions, orange production in Florida is projected to decrease from 194 million boxes in 2007–08 to a low of 155 million boxes in 2019–20 and then rise to 156 million boxes in 2020–21. Bearing acreage is projected to be 535,000 acres in 2020–21 compared to 576,000 acres in the baseline. Greening is also projected to impact orange production in Sao Paulo with production decreasing from 342 million boxes in 2007–08 to a low 331 million boxes in 2011–12. Thereafter, production is projected to slowly increase recovering to 385 million boxes in 2020–21. Projected production in Sao Paulo in 2020–21 is 83 million boxes (18%) less under the "low greening" assumptions compared to the baseline.

With lower production in Florida and Sao Paulo, projected prices under "low greening" are substantially higher compared to the baseline assumptions. FOB FCOJ prices are projected to increase from $1.24 per SSE gallon in 2007–08 to a high of $1.75 in 2017–18 and then moderate thereafter. Florida on-tree prices for processed oranges show a similar increase from $4.31 per box to $7.50 per box in 2018–19 moderating to $7.44 per box in 2020–21. Lower orange production in Sao Paulo and Florida also affects OJ consumption with U.S. consumption in 2020–21 estimated at 1.370 billion SSE gallons vs. 1.545 billion SSE gallons in the base or no-greening scenario, an 11% decline; there is little change, however, in U.S. OJ consumption over the forecast horizon. ROW consumption decreases from 2.151 billion SSE gallons in 2007–08 to 2.032 billion SSE gallons in 2013–14 and then modestly increases to 2.222 billion SSE gallons in 2020–21. ROW OJ consumption in 2020–21 for the "low greening" assumption is 18% less than for the base scenario (2.702 to 2.222 billion SSE gallons).

In Table 4, long-run projections of production and prices for oranges and orange juice are shown under the "high greening" scenario. Under these assumptions, Florida orange production is profoundly impacted with projected production decreasing from 194 million boxes in 2007–08 to 123 million boxes in 2020–21. Although Florida production appears to be stabilizing by 2020–21, projected production falls throughout the forecast horizon. The impact of greening on Sao Paulo is also profound as projected production ranges from 331 million boxes in 2007–08 to a low of 300 million boxes in 2012–13 and then recovering to 350 million boxes in 2020–21. A significant result, however, is that even under the high tree mortality rates assumed in this scenario, orange production in both Sao Paulo and Florida persists, albeit at lower levels compared to the baseline.

With greening adversely affecting production in both Florida and Sao Paulo, orange juice prices are significantly higher under the "high greening" scenario. Florida bulk FOB FCOJ prices are projected to be $1.28 per SSE gallon in 2007–08 and increase to $2.12 per SSE gallon in 2018–19 and moderate to $2.09 per SSE gallon in 2020–21. With lower supplies, consumption is also negatively affected with U.S. OJ consumption decreasing from 1.368 billion SSE gallons in 2007–08 to a low of 1.208 billion SSE gallons in 2016–17 and then increasing to 1.253 billion SSE gallons in 2020–21. Consumption is projected to be nearly 19% lower in this scenario compared to the baseline in 2020–21. Consumption in the ROW is projected at 1.922 billion SSE gallons, a level of 780 million SSE gallons lower than that projected in the baseline.

Table 3. Long-run projections of Florida and São Paulo orange production, U.S., and "rest of the world" (ROW) orange juice (OJ) consumption and U.S. OJ prices, base assumptions PLUS low-greening-loss rates.[z]

	Orange							
					Price		OJ consumption	
Season	Florida production (million boxes)	Total acreage (1000 acres)	Acre-loss rate (%)	São Paulo production (million boxes)	Florida bulk FCOJ ($/SSE gal)	Processed on-tree ($/box)	U.S. (million SSE gal)	ROW (million SSE gal)
2007–08	194	504	–3.5	342	1.24	4.31	1383	2151
2008–09	191	497	–3.4	337	1.31	4.71	1370	2125
2009–10	186	499	–3.5	334	1.37	5.14	1356	2097
2010–11	183	501	–3.7	332	1.44	5.54	1345	2076
2011–12	177	502	–4.2	331	1.50	5.96	1333	2053
2012–13	172	502	–4.7	332	1.57	6.34	1324	2039
2013–14	167	502	–4.8	335	1.62	6.68	1318	2032
2014–15	163	503	–4.8	338	1.67	6.97	1316	2033
2015–16	160	506	–4.7	343	1.70	7.20	1316	2043
2016–17	157	511	–4.6	350	1.73	7.37	1320	2062
2017–18	156	516	–4.5	357	1.75	7.47	1328	2090
2018–19	155	522	–4.4	366	1.75	7.50	1340	2128
2019–20	155	528	–4.3	375	1.75	7.49	1354	2172
2020–21	156	535	–4.2	385	1.74	7.44	1370	2222

[z]Same as base scenario (Table 2), except greening is assumed to increase base scenario tree mortality rates, Florida acre-loss rates by 100% for non-bearing trees, by 75% for 4- through 11-year-old trees, and 50% for trees over 11 years old; and increase tree-loss rates in São Paulo by 50% (5% to 7.5%); FCOJ = frozen concentrated orange juice; SSE = single-strength equivalent.

Table 4. Long-run projections of Florida and São Paulo orange production, U.S., and "rest of the world" (ROW) orange juice (OJ) consumption and U.S. OJ prices, base assumptions PLUS high-greening-loss rates.[z]

	Orange							
					Price		OJ consumption	
Season	Florida production (million boxes)	Total acreage (1000 acres)	Acre-loss rate (%)	São Paulo production (million boxes)	Florida bulk FCOJ ($/SSE gal)	Processed on-tree ($/box)	U.S. (million SSE gal)	ROW (million SSE gal)
2007–08	194	504	–3.5	331	1.28	4.53	1368	2113
2008–09	191	497	–3.4	321	1.37	5.09	1345	2061
2009–10	186	499	–3.6	313	1.46	5.67	1323	2011
2010–11	181	500	–4.2	307	1.55	6.24	1302	1967
2011–12	172	496	–5.8	303	1.65	6.89	1278	1915
2012–13	162	486	–7.2	300	1.76	7.55	1256	1867
2013–14	153	477	–7.6	300	1.86	8.19	1235	1826
2014–15	144	472	–7.5	302	1.95	8.75	1220	1798
2015–16	137	470	–7.2	305	2.02	9.20	1211	1784
2016–17	132	471	–6.9	311	2.07	9.53	1208	1784
2017–18	128	475	–6.6	318	2.11	9.72	1211	1799
2018–19	125	480	–6.4	327	2.12	9.79	1220	1829
2019–20	124	487	–6.1	338	2.11	9.74	1235	1870
2020–21	123	495	–5.9	350	2.09	9.60	1253	1922

[z]Same as base scenario (Table 2), except greening is assumed to increase base scenario, Florida acre-loss rates by 300% for non-bearing trees, by 200% for 4- through 11-year-old trees, and 150% for trees over 11 years old; and increase tree-loss rates in São Paulo by 50% (5% to 9%); FCOJ = frozen concentrated orange juice; SSE = single-strength equivalent.

Discussion

The projections shown in Tables 2–4 demonstrate the large impacts that citrus greening could cause in Sao Paulo and Florida. Given the experience of citrus greening in Asia and Africa, it is well known that this is a highly destructive disease that is difficult to control, in part, because it has hosts other than citrus. Projected large price effects mean that consumers as well as producers will bear the cost of the disease. With FOB FCOJ prices nearly double in the "high greening" scenario compared to the baseline, consumers will bear a heavy burden if the assumptions associated with the "high greening" scenario prove to be accurate.

A main assumption of the analysis that helps generate high FOB and on-tree prices is that other citrus producing regions will not be able to significantly expand processed orange production over the forecast horizon. These other regions presently include Mexico, Belize, Costa Rica, China, Cuba, and Australia. In this paper, the outlook for citrus production in each of these countries has not been extensively discussed except to note that each of these regions face significant constraints to greatly expand processed orange production. Even if capital were to flow into one or more of the regions, the lag time to significantly expand processed orange production is at least 10 years given the lag between new tree planting and realized changes in production. To our knowledge, there is no evidence at this time that a major expansion is being planned in any of these countries.

Concluding Remarks

Citrus greening has been found in the two major processed orange producing regions: Sao Paulo and Florida. With the Asian citrus psyllid present in both locations, an efficient vector is present to spread the disease throughout the citrus producing area of both regions. In this paper, an attempt is presented to quantify the likely effects of the disease on orange production in both regions and consequently on orange juice prices.

Since the actual impact of the disease on tree mortality is not yet known, the results presented herein must be treated as hypothetical. An attempt has been made to make plausible assumptions about the likely effect of the disease on tree mortality and then project those changes of tree mortality on fruit production and prices. It is possible that as the disease is better understood and appropriate management interventions are implemented, that even the "low greening" scenario is too pessimistic and the actual effect of tree mortality will be less than that conjectured in that scenario. On the other hand, it is also possible that the disease will have more severe effects than envisioned under the "high greening" scenario. Even though the processed orange industries of Sao Paulo and Florida are projected to survive under the "high greening" scenario, substantially higher tree mortality would bring that conclusion into question.

Thus, it is clear that a major research effort is needed from the scientific community related to citrus that encompasses a wide range of issues, including disease transmission and psyllid control, management practices to limit the impact of the disease in infected blocks, and development of disease-resistant varieties.

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