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An Economic Model of Long-run Supply and Demand Forecasts for Florida Oranges

Matthew J. Salois*, Carlos E. Jauregui, and Mark G. Brown

Florida Department of Citrus, Economic and Market Research Department, University of Florida, 2125 McCarty Hall, P.O. Box 110249, Gainesville, FL 32611-0249

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This paper presents an economic model of long-run production and consumption forecasts for Florida oranges. This is accomplished through a quantitative model of the world orange juice market. By conducting model simulations, possible answers to key questions about the future of the Florida citrus industry are provided. Will prices be high enough to cover costs? What will be the size of the Florida citrus industry in the future? What will be the impact of the citrus industry on the Florida economy? Although answers to such questions can only be provided in a probabilistic sense, such answers are critical for future planning purposes.

The model used to examine how different external factors including citrus canker, greening, land development, and cost increases may impact the Florida citrus industry are discussed in this paper. While these factors mainly affect supply, demand may also be affected due to losses in export and domestic markets. For example, Europe, California, Texas, and Arizona, where citrus is produced locally, could bar imports from areas where canker is present. On the supply-side, canker, greening, and use of citrus lands for residential and commercial development could significantly reduce Florida citrus production. Living with canker and greening can also be expected to result in higher costs as additional resources will be required to minimize and manage these diseases. Increases in citrus land values resulting from demand for land for development would also impact grower costs.

The model for orange juice (OJ), the largest revenue-producing citrus product in Florida, is derived. (Discussion of the model is based on the appendix B in Spreen et al., 2006.) The model discussed here focuses on supply and demand changes and the price environment that may occur as a result of the above mentioned factors. The OJ model is comprised of general relationships between OJ supply, demand, and prices in the world. Econometric estimates of these relationships are then used to simulate the model. The conceptual model is discussed first, followed by a discussion of OJ supply and then OJ demand. Lastly, results from the production forecast are discussed.

Conceptual Model

Let $Q(p,t)$ and $q(p,t)$ be world OJ supply and demand, respectively, where t is time and p is the Florida FOB price for bulk frozen concentrated orange juice. In this model, the FOB price p is used as an approximation of the world price, based on the relatively high correlation between this FOB price and other world OJ prices over time. The variable t is used to indicate changes over time in supply and demand (with prices constant). Supply may change, for example, because of canker greening, hurricanes, and use of citrus acreage for alternative uses. Demand may change, for example, due to possible consumer income growth, advertising, and enhanced preferences.

In reality, the market for OJ is comprised of a number of differentiated products. OJ is differentiated by product form, such as frozen concentrated orange juice (FCOJ) and not-from-concentrate (NFC), as well as attributes including ratio, color, and viscosity. In principle separate demands for each differentiated product could be specified as a function of the product's own price and the cross prices of all the other differentiated OJ products, as well as other variables such as prices of other goods and consumer income. However, given these OJ products are close substitutes, their price tend to be highly correlated instigating problems of multicollinearity, and estimates of separate own and cross price parameters is problematic. Thus, based on the high correlation of prices, OJ is modeled here as a single product with one price as an approximation.

In equilibrium, price is at a level such that supply equals demand, that is,

$$Q(p,t) = q(p,t) \tag{1}$$

An important part of the model is how changes in supply and demand impact price. If supply Q grows faster than demand q, price will tend to decrease and vice versa; if supply and demand change by the same amount, price will tend to remain constant. These price tendencies can be formalized by totally differentiating equation (1) and solving for the price change dp, where d before a variable indicates a change in that variable. In this case, $dp = p_t - p_{t-1}$, where time subscripts have been added. In mathematical terms,

$$\left[\frac{\partial Q}{\partial p}\right]dp + \left[\frac{\partial Q}{\partial t}\right]dp = \left[\frac{\partial q}{\partial p}\right]dp + \left[\frac{\partial q}{\partial t}\right]dt \tag{2}$$

or rearranging terms yields,

$$dp = \frac{\left[\frac{\partial q}{\partial t}\right]dt - \left[\frac{\partial Q}{\partial t}\right]dt}{\left[\frac{\partial Q}{\partial p}\right] - \left[\frac{\partial q}{\partial p}\right]} \tag{3}$$

*Corresponding author; phone: (352) 392-1874; email: msalois@ufl.edu

The supply slope is positive or $\partial Q/\partial p > 0$, and the demand slope is negative or $\partial q/\partial p < 0$; thus the denominator of equation (3) is positive or $(\partial Q/\partial p - \partial q/\partial p) > 0$. If demand and/or supply grows, contracts, or is unchanged, the terms $(\partial q/\partial t)dt$ and $(\partial Q/\partial t)dt$ would be positive, negative, or zero, respectively. The strengths of these supply and demand changes determine the price change. For example, if there is no price change in demand, so that $(\partial q/\partial t)dt = 0$, and supply grows or $(\partial Q/\partial t)dt > 0$, then price will fall, $dp < 0$, according to equation (3). Thus, with growth in supply, growth in demand is needed to prevent price from decreasing.

OJ Supply

World OJ supply in a given year is specified as:

i) Beginning OJ inventories in Florida sourced from the Florida Citrus Processors Association (FCPA) plus,
ii) Beginning OJ inventories in Brazil sourced from the USDA/FAS plus,
iii) Florida OJ production plus,
iv) Other U.S. OJ production plus,
v) Brazil OJ production plus,
vi) Rest-of-the-world (ROW) OJ production.

Beginning inventories are predetermined based on previous season supply and demand. Florida OJ production is based on the Florida orange crop which is determined by Florida bearing orange acreage times boxes of fruit per acre, by tree age sourced from Florida Agricultural Statistics Service (FASS). The part of the model for Florida orange production is an extension of a model used by the Florida Department of Citrus (FDOC) to project production; see "Florida Citrus Production Trends, 2012–13 through 2020–21," for further discussion of this component of the model. Acreage, yield, and orange production estimates are disaggregated by early and midseason oranges (EM) and late or Valencia oranges. The initial acreage, upon which the future production projections depend, is based on the bearing trees reported by FASS for the most recently available season, here the 2009–10 season. The bearing acreage in 2010–11 is the surviving 2009–10 bearing acreage plus surviving acreage planting in 2007 (the maturation of non-bearing 2-year-old trees to bearing 3-year-old trees). Acreage in subsequent years is similarly recursively determined.

Acreage losses due to canker, greening, hurricanes, and development enter the model through assumed loss rates used in projecting the acreage forward through time. Cost increases due to these factors also enter the model through planting equations (as will be discussed subsequently). Additionally, yields per care are dependent on assumed acreage infected with canker. For infected acreage, yields for early and midseason oranges and late oranges are assumed to decrease by 10% and 5%, respectively. Yields are also adjusted for the possibility of hurricane losses. Average yields from the most recent seasons after the 2006–07 seasons are used to represent yields in non-hurricane seasons, while yields in the hurricane impacted seasons of 2004–05 are used to represent yields in future hurricane impacted seasons. For example, if the probability of a future hurricane is set at 10%, the future yields used in the simulation are weighted averaged calculated as 90% of the non-hurricane yields plus 10% of the hurricane yields.

Florida orange planting equations are used in the model to determine acres planted. The planting equations link prices to future supply. The general planting specification for both EM and late varieties of oranges used is:

$$n_t = a + bp^e_{f,t} \tag{4}$$

where n_t is the number of acres planted, $p^e_{f,t}$ is the expected futures price for FCOJ at time t, and both a and b are estimated (positive) parameters. An adaptive expectations specification is used to model the expected price: $p^e_{f,t} = \lambda p_{f,t-1} + (1 - \lambda)\, p^e_{f,t-1}$, where $p^e_{f,t-1}$ is the actual futures price at time $t - 1$, deflated by the consumer price index (CPI) and λ is a parameter between zero and one, previously estimated to be 0.73 in this paper.

The impacts on planting levels due to cost changes such as the increase in the cost of citrus land related to the demand for land for development are considered by adjusting the intercept in equation (4). It is assumed that the expected delivered-in price differs from the expected futures price by a constant, that is, $p_d^e = a_1 + p_f^e$ where p_d^e is the expected delivered-in price and a_1 is the constant term. An expected net grower price is specified as $p_n^e = p_d^e - c$, where c represents costs. Hence, through substitution, $p_n^e = a_1 + p_f^e - c$. Using this result, the planting equation can be written as

$$n_t = a_0 + bp^e_{n,t}$$

or

$$n_t = a_0 + b(a_1 + p^e_{f,t} - c_t)$$

or

$$n_t = a + bp^e_{f,t}$$

where

$$a = (a_0 + ba_1 - bc_t)$$

The above result implies that if costs change by dc, then the intercept a changes by the amount $b{\cdot}dc$. Thus, given that b is positive, an increase in costs results in a decline in the planting level of $b{\cdot}dc$. Equation (4) is incorporated into the model in difference from

$$(n_t - n_{t-1}) = b(p^e_{f\,t} - p^e_{f,\,t-1}) - b(c_t - c_{t-1})$$

or

$$n_t = n_{t-1} + b(p^e_{f,t} - p^e_{f,t-1}) - b(c_t - c_{t-1})$$

Processed orange utilization is estimated as boxes of Florida oranges produced, as determined above, minus an assumed fresh utilization level (certified and noncertified). An average juice yield per box is then applied to the processed orange utilization estimate to obtain OJ production. Additionally, OJ production from specialty citrus production is estimated by multiplying an average specialty processed utilization rate times specialty citrus production times the average juice yield. Specialty citrus production is assumed to follow the same trends as orange production over the projection period.

Other U.S. OJ production is set at the average level over the most recent five-year period, while ROW OJ production is based on data reported in by the USDA/FAS in the Production, Supply, and Distribution Online Database. In the model, ROW OJ production is assumed to grow by 1% annually.

Brazil's OJ production is estimated similarly as Florida's. Sao Paulo's bearing and non-bearing trees (obtained from USDA/FAS) are projected forward based on an assumed tree-loss rate and planting equation. Sao Paulo orange production is then estimated as the projected bearing trees times an average yield per tree. Sao

Paulo processed orange boxes are estimated as production minus an assumed fresh utilization level held constant over the projection period. Sao Paulo OJ production is then estimated as processed orange boxes times an average juice yield. OJ production outside of Sao Paulo in Brazil is estimated as constant, based on recent levels. The planting equation for Sao Paulo is

$$n_{b,t} = e + fp^{e}_{fs,t}$$

where $n_{b,t}$ is the number of trees planted, $p^{e}_{fs,t}$ is an expected price ratio of the FCOJ futures price divided by the Brazil sugar price, and and e are f estimated parameters. As in the Florida planting equation above, an adaptive expectations specification is used to model the expected price variable. Growing sugarcane is an important alternative land use for citrus acreage in Brazil. About half of Brazil's sugarcane is used in producing ethanol. Recent energy price increases have resulted in increases in demand for ethanol, which, in turn, has resulted in increases in ethanol and sugar prices, making sugarcane production more profitable.

Based on estimates of the above supply components, season-to-season changes in aggregate OJ supply, $(\partial Q/\partial t)dt$ in equation (3), can be determined. To obtain an estimate of the price change (dp), estimates are needed of the change in world demand with prices constant or $(\partial q/\partial t)dt$ and the world demand slope or $\partial q/\partial p$. For season-to-season changes, the supply slope, $\partial Q/\partial p$, is assumed to be zero. In the long-run this slope is positive based on planting equations (4) and (5). It takes about 3 years for a newly planted tree to produce oranges for commercial use. Thus, even though the current price, as well as past prices, impact current planting levels in the model, because of the lag between planting year and the year in which the newly planted trees bear fruit, the current price does not impact current production in the model. Thus, based on equation (3), the season-to-season change in the price of OJ is calculated as

$$dp = \frac{(\partial Q/\partial t)dt - (\partial q/\partial t)dt}{(\partial q/\partial p)} \tag{6}$$

The numerator of this equation indicates excess supply, excess demand, or neutral supply and demand shifts, when its sign is positive, negative, or zero respectively. The inverse of the term $(\partial q/\partial p)$ or $(\partial p/\partial q)$ transforms the excess supply or demand into a price change.

OJ Demand

Demand growth rates are assumed to determine the volume (gallon) change in world demand, $(\partial q/\partial t)dt$. In the model, world demand is disaggregated into five components. Each of these components along with a baseline demand growth assumption is:

i) U.S. OJ consumption: 1%,
ii) U.S. OJ exports: 1%,
iii) ROW consumption: 2%,
iv) Florida ending OJ inventory: 1%,
v) Brazil ending OJ inventory: 1%.

For each component, the growth rate times the previous period demand component level yields an estimate of the volume growth in demand for the component. The sum of these component volumes provides an estimate of $(\partial q/\partial t)dt$.

The last term needed to determine the price change, equation (6), is the world demand slope $(\partial q/\partial p)$. This term is calculated as the sum of the FOB price slopes for the five world OJ demand components above. World demand can be written as

$$q = \sum_{i=1\ldots5} q_i(p_i,t) \tag{7}$$

where i stands for a component and $p_i = p + m_i$ or the FOB price for component i with m being the margin between the Florida FOB p and the FOB price for component i. Differentiating world demand with respect to price p results in

$$\partial q/\partial p = \sum_{i=1\ldots5} q_i(p_i,t)$$

The component quantity-price slopes, $\partial q_i/\partial p_i$, are based on previous research (Brown et al., 2004; Spreen et al., 2003; Ward et al., 2006) and recent preliminary demand estimates. The FOB price elasticity estimates for U.S. OJ consumption, U.S. OJ exports, and ROW OJ demand are –0.34, –0.66, and –0.40, respectively. The Florida and Brazil inventory elasticity estimates are –0.56 and –0.88, respectively. The five elasticities, defined by

$$\varepsilon_i = (\partial q_i/\partial p_i)(p_i/q_i)$$

are transformed into quantity-price slopes based on the relationship

$$\varepsilon_i = (q_i/p_i)(\partial q_i/\partial p_i)$$

The price based on equation (6) is such that world demand exactly equals world supply. The demand level for each component is calculated based on the differential of the component's demand, that is,

$$dq_i = (\partial q_i/\partial p_i)dp + (\partial q_i/\partial t)dt$$

or

$$q_{i,t} = q_{i,t-1} + (\partial q_i/\partial p_i)dp + (\partial q_i/\partial t)dt.$$

In other words, the current-period component demand is the previous period component demand plus the component demand slope times the price change from equation (6) plus the assumed volume growth rate for the component times the previous demand volume.

Production Estimates

Orange production projections are shown in Table 1. (Production projections are based on the findings in Brown, 2011.) The table footnotes describe the assumptions undertaken. The low tree loss scenarios suggest production levels may be moderately declining to somewhat flat over the next ten years. A key assumption is that groves under nutritional programs will largely be kept in production. The higher loss rate scenarios, provided to account for the uncertainty of the latter assumption, indicate the possibility of more severe production declines.

It is difficult to attach probabilities to the different orange production scenarios in Table 1, but the relatively low-acreage-loss scenarios (first set of three scenarios on the left-hand-side of the table) may have the highest probability of occurrence to the extent the citrus psyllid population and greening or HLB can be controlled, planting activity increases, and nutritional programs are effective. Continued progress in dealing with production problems, along with the decision being made by many growers to invest in new plantings, support the more optimistic production scenarios.

Table 1. Florida orange production projections, actual for 2007-08 through 2009-10, FASS January estimate for 2010-11, and FDOC estimates for 2012-13 through 2020-21, Based on Average Yields.[a]

Season	LOSS								
	Low[b]			Middle[b]			High[b]		
	PLANTING								
	Low[c]	Middle[d]	High[e]	Low[c]	Middle[d]	High[e]	Low[c]	Middle[d]	High[e]
	- - - - - - - - - - - - - - - - million boxes - - - - - - - - - - - - - - - -								
2007-08	170	170	170	170	170	170	170	170	170
2008-09	163	162	162	162	162	162	162	162	162
2009-10	134	134	134	134	134	134	134	134	134
2010-11	140	140	140	140	140	140	140	140	140
2012-13[f]	144	144	144	138	138	138	132	132	132
2013-14	142	142	143	133	134	134	125	125	126
2014-15	140	141	142	129	130	131	119	120	121
2015-16	139	140	141	125	127	129	113	115	117
2016-17	137	139	141	122	124	127	108	111	114
2017-18	134	137	140	118	122	125	103	107	111
2018-19	132	136	140	114	119	124	99	104	109
2019-20	130	135	140	111	117	123	94	101	108
2020-21	128	134	139	108	114	122	90	98	106
avg. loss[g]	-3.9%	-3.9%	-3.9%	-5.9%	-5.8%	-5.8%	-7.9%	-7.8%	-7.7%
avg. plant.[h]	1.8	1.8	2.5	1.6	2.6	3.7	2.1	3.4	4.9

[a] Assumes yields are average from 2007-08 through 2009-10; for acreage with citrus canker, yields were reduced by 10.0% for early and midseason oranges, 5.0% for Valencia oranges.
[b] Assumes loss rates vary by age, lowest for young trees (0-3 yrs), highest for middle age tree (4-11 yrs) and more moderate for older trees (12-24 yrs), given incidence of HLB.
[c] Half of replacement planting level (roughly average planting level).
[d] Three-fourths of replacement planting level.
[e] Replacement planting level.
[f] A forecast for 2011-12 will be made in October, 2011, by the USDA, Florida Agricultural Statistics Service.
[g] Unweighted average acre loss rate per year (%) over projection period.
[h] Unweighted average million trees planted per year over projection period.

Conclusions

The models described above are, of course, a simplification of the real world. Some simplification is necessary to examine the economic complexity underlying the Florida citrus industry. The focus has been on variables considered to be important for the future of the industry. Nevertheless, it is difficult to predict the course that some explanatory variables may take, and the estimated relationships may change over time. Additionally, variables that may seem insignificant today and left out of the analytical model may become major factors tomorrow.

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